# THE JOURNAL OF ENGINEERING EDUCATION

Published by the Society for the Promotion of Engineering Education

Published under the supervision of the Publication Committee.
R. I. Rees, Dexter S. Kimball, F. L. Bishop, Editor, University of Pittsburgh.
Published at Lancaster, Pa.

Entered as second-class matter at the Post Office at Lancaster, Pa., under the Act of March 3, 1870.

New Series
Vol. XX, No. 6. FEBRUARY, 1930 Subscription Price, $3.00 per year. Single Copies, 50 cents

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# DIFFERENTIAL EQUATIONS AS A FOUNDATION FOR ELECTRICAL CIRCUIT THEORY *

By THORNTON C. FRY

Bell Telephone Laboratories, New York City

## §1. Introductory Remarks

The subject of electrical circuit theory is of fundamental importance, not only in the field of Communication, but in power engineering as well. From the physical standpoint it is naturally a study in real quantities, since the physical forces and currents are themselves real, and the mathematical methods originally used in connection with it dealt almost exclusively with real variables. During the present century, however, a progressive transition has taken place, until now the use of complex quantities is by all odds the usual thing, and real numbers are rather rare. This transition has been brought about, not through the influence of mathematicians who have taught the engineers the advantage of complex quantities, but rather through the initiative of a few engineers who have preached the idea to their own kind. As a natural consequence the duty of explaining why *imaginary* numbers are so peculiarly appropriate in a problem in which the physical quantities are so obviously *real* has fallen to the professor of electrical engineering, though the reasons are essentially mathematical in character, and can be taught much more concisely and effectively in connection with a study of elementary differential equations. It is my purpose to emphasize this fact by outlining as briefly as possible the nature of the problem, and the ideas upon which its solution is based.

Perhaps the matter would be of little consequence if the results were satisfactory, but this is not the case. For, simple

* Presented before the American Mathematical Association, Boulder, Colo., August 28, 1929, and published in the American Mathematical Monthly.

as we shall find the ideas to be when presented in a suitable setting, they are really so foreign to the subject of electricity itself that it is not easy to explain them effectively in a technical course. Hence, even if the instructor has the proper perspective, which is not always the case, he usually meets his immediate needs by some sort of vectorial analogy, and the student is left with a very hazy idea as to what it is all about. The accuracy of this statement will be readily attested by those mathematicians who have occasion to meet representative groups of such students after graduation.

## §2. The Differential Equations of Circuit Theory

The differentiated equations of elementary circuit theory—and the same is true of the simpler dynamical systems in general—are characterized by five principal characteristics:

1. They are linear.

Of course, any dynamical system can be overloaded to the point where it becomes non-linear. Very frequently, however, its practical usefulness ceases when non-linearity sets in, and because of this fact we are justified in thinking of it as a linear system. There is also another class of dynamical systems, of which vacuum-tube devices are excellent electrical illustrations, many of whose uses depend upon the fact that they are essentially non-linear in character. Such systems, however, require special methods of treatment, and are not usually regarded as part of the subject-matter of "elementary" circuit theory. Moreover, the physical peculiarities of the systems play such a fundamental part in their discussion that the mathematician is likely to treat them less effectively than the engineer.

2. The coefficients are constant.

This also is only true within certain limits; but when it is not the problem is no longer "elementary" in the sense in which we are using the term.

3. There are usually several dependent variables, so that the problems formulate themselves as *systems* of differential equations, rather than single equations.

It is often true that all but one of these variables are without any technical interest. In such cases, of course, the problem could be expressed either as a single equation of high order or as a system of low order. But even when this is true, the nature of the boundary conditions is usually such that the use of the system is to be preferred.

4. Very frequently—so frequently in fact as to merit almost exclusive attention in an elementary course—the boundary conditions are given by one or the other of two physical statements: either the system is "at rest" at a certain instant, or else it is in a "steady state."

5. The driving force which actuates the system is usually of the simple harmonic (a.c.) type $E_0 \cos(pt - \epsilon)$, constant (d.c.) forces being included as the special case $p = 0$.

Superficially, there are two reasons why this type of driving force should be so nearly universal. The first is the dynamical fact that rotating generators and oscillating circuits produce electromotive forces of substantially this type. The second is the fact that it is the basis function out of which Fourier series and Fourier integrals are built.

The first of these reasons is a fundamental one. It is inherent in the nature of the systems with which we deal. The second, however, is only superficially different, since the superiority of Fourier expansion to other forms, Hermite polynomials for instance, resides primarily in the fact that simple harmonic oscillations are characteristic of linear dynamical systems.

Reduced to mathematical terms, then, the problem of elementary circuit theory is that of solving the system of differential equations:

$$\left.\begin{aligned} F_{11}(p)y_1 + F_{12}(p)y_2 + \cdots + F_{1r}(p)y_r &= f_1(t), \\ F_{21}(p)y_1 + F_{22}(p)y_2 + \cdots + F_{2r}(p)y_r &= f_2(t), \\ \cdots\cdots\cdots\

quire that the system shall be either at rest or else in a steady state at the time zero.

I need scarcely remark that the study of such systems is a recognized part of first courses in differential equations. The suggestion that the foundation for circuit theory should be laid in such courses is therefore not a very revolutionary one: it requires at most only a slight change of emphasis to accomplish it. Perhaps this will become even clearer as we mention the four facts upon which the use of complex quantities rest, none of which is unusual or non-mathematical in character.

## §3. The Principle of Superposition and the Principle of Decomposition

Two of these four facts are properties of linear differential equations. They are generally known in applied mathematics as the principle of superposition and the principle of decomposition. In order to simplify their wording it is desirable to call any set of $y$'s which satisfies (1) a solution "due to" the functions $f_j(t)$, the phrase being suggested by the fact that, in the electrical applications, the $y$'s are currents and the $f$'s electromotive forces. If we adopt this form of speech, the principle of superposition becomes:

*The sum of any solution of* (1) *due to the set* $f_j$ *and any solution due to another set* $g_j$ *is a solution due to* $f_j + g_j$. Of course, if this theorem is true for two sets of functions, it is true for any finite number.

The principle of superposition is of importance because it enables us to simplify our problem in three ways:

In the first place, we can consider the $r$ sets of functions

$$\begin{array}{cccccc} f_1, & 0, & 0, & \cdots, & 0 \\ 0, & f_2, & 0, & \cdots, & 0 \\ 0, & 0, & f_3, & \cdots, & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ 0, & 0, & 0, & \cdots, & f_r \end{array}$$

separately, and by adding together the results thus obtained find a solution due to the set

$$f_1, \quad f_2, \quad f_3, \quad \cdots, \quad f_r.$$

In other words in the development of the theory we may assume that all of the $f$'s except one are zero; and since the order in which the equations are written is immaterial, we may always suppose that the one which does not vanish is the first.

In the second place, if the one driving force which remains is the sum of a number of simple harmonic terms (as it will be if it can be represented by a Fourier series or integral) we may consider each of these terms separately and add the results together. In other words, in the development of our theory we may assume that the one $f$ which does not vanish is a single trigonometric term.

The third simplification is, in reality, a sort of inverse use of the theorem. Of course, there is no *exact* converse of the principle of superposition, for even if we know a solution of (1) due to $f_j + g_j$, we cannot ordinarily separate the part which is due to $f_j$ from that which is due to $g_j$. But there is one exceptional case in which the component parts can be recognized. *It occurs when the functions $f_j$ are real while the functions $g_j$ are pure imaginary; for then the real part of a solution due to $f_j + g_j$ is a solution due to $f_j$ and the imaginary part is a solution due to $g_j$.*

This is the principle of decomposition.

## §4. Two Peculiarities of Exponential Functions

The other two facts upon which the use of complex quantities in electrical network theory is based are even more elementary. They are:

*The derivatives of an exponential function are proportional to the function itself.*

I need hardly remark that it is this property which enables us to reduce the system of *differential* equations (1) to a system of *algebraic* equations, and thus determine, in the traditional way, not only the complementary part of the solution due to any sort of function [1] $f(t)$, but also a particular solution as well when $f(t)$ happens to be exponential.

[1] Since we may now assume that all the $f_j$'s except one are zero, we need no subscript to distinguish this one which remains.

*The other important property of the exponential function is Euler's equation,* $e^{ix} = \cos x + i \sin x$.

## §5. Complex Numbers in Electrical Circuit Theory

With these four properties before us, the reason for using complex quantities is readily seen. For if it is true that the system (1) can be easily solved when $f(t)$ is an exponential, and if it is true that when $f(t)$ is complex we can separate out the solution due to its real part from the solution due to its imaginary part, it follows at once that we can easily obtain the solution due to a simple harmonic function $\cos(pt-\epsilon)$ by first finding the solution due to a complex exponential $e^{i(pt-\epsilon)}$, and then discarding its imaginary part.

This is the entire argument in favor of the use of complex numbers in electrical circuit theory. It is hard to imagine any explanation based upon vectorial ideas which would approach it either in conciseness, simplicity or generality. Indeed, there is none *provided the matter is brought up during a discussion of differential equations.*

But suppose it is not. Suppose instead that it arises in a technical course and that the class either has not been exposed to the argument at all, or else that the form of presentation has not been so molded as to conform in some degree to their technical needs. It is obvious that the engineering instructor must then either present a connected account of part of the theory of linear differential equations, or else he must find some brief but plausible explanation of what he proposes to do. He may *suspect* that if he chooses the latter alternative his students may some day have to unlearn some crude ideas; but he *knows* that the other will sacrifice time which he needs for the presentation of technical ideas. If we remember where his interest lies, there is little doubt which alternative he will choose.

## §6. The Steady State Solution; Impedance; Natural Frequencies; Damping

I think it must now be evident why I believe that this subject matter should be presented in the mathematical instead

of the engineering classroom, and why I believe the subject of differential equations should be required of those students who are likely to be interested in circuit theory. So far, however, I have spoken only of its desirability from the standpoint of the engineer himself. I believe, however, that with comparatively little effort the subject may be made to yield a return to the mathematician also in increasing his fund of illustrative material, and in deepening the interest of his class.

I need hardly mention the fact that the imaginary parts of the roots of the auxiliary equation give us the "natural frequencies" of the system, and the real parts the "damping." Few instructors would fail to mention such obvious facts, at least when talking to a class with practical interests. But once we have introduced the electrical circuit as a sort of collateral objective, a number of ideas suggest themselves which might otherwise not be thought of. For instance, since the particular solution (which we obtain by algebraic means when we deal with exponential or sinusoidal forces) is independent of the boundary conditions, we at once suspect that it must correspond to the steady-state condition of the system. It is a simple matter to verify this assumption. Conversely, the solution of the complementary equation can be obtained once for all without any knowledge of the nature of the driving force, except in so far as that knowledge enters into the evaluation of the constants of integration. We would therefore suspect it to be the "transient" reaction of the circuit, and again it is a simple matter to prove that this is true.

We may also observe that the particular (or steady-state) solution is obtained by merely writing down a few determinants, whereas in order to find the complementary (transient) part it is necessary to locate the roots of an algebraic equation. As the first of these processes is very much simpler than the second, we conclude that it will in general be immensely simpler to find those properties of a system which are defined in terms of its steady-state reaction, than to find its transient reaction to impulses and the like. Chief among the ideas associated with the steady state is that of impedance, which is defined as the ratio of the driving force to the steady-state

current which it produces. It follows at once that the impedance of the system is just the ratio of the two determinants by means of which our particular solution is derived. In this connection we may observe that in the days when electrical theory was a science of real numbers, it was the ratio of the *magnitudes* of these two quantities which was called impedance, but today the term is applied about equally often to this real quantity, and to the complex ratio itself.

Also, if we separate the driving force into two components, one in phase with the current and the other 90° out of phase, the ratios obtained when we divide these two components by the current are called the "resistance" and "reactance" of the circuit, respectively. It requires only a moment's inspection to show that these definitions merely state that the resistance of a circuit is the real part of its impedance, and the reactance the imaginary part.

How much of this sort of illustration should be used depends, of course, upon the interests of the instructor and the needs of his class. In some cases it might be unwise to use even so much as I have mentioned; in others it might be desirable to speak of such matters as Rayleigh's reciprocity theorem and Heaviside's expansion. Very often the presentation of Cauchy's solution, at least in the simplified form which corresponds to the case of a system originally at rest, will be of interest, not only because of its technical importance but also because it is a beautiful piece of mathematics in itself.*

I hold no brief as to just which of these things shall be done, or indeed as to how they shall be done, my only point being that in my opinion both the mathematician and the engineer will benefit from the doing of them: the engineer because of the more suitable foundation which will be laid for his technical work, and the mathematician through the fact that his subject will have a vitality and interest which is too often lacking when the study of the linear system is merely an exercise in $p$'s, D's and $\theta$'s.

* See F. D. Murnaghan, *"The Cauchy-Heaviside expansion formula and the Boltzmann-Hopkinson principle of superposition."* Bulletin of the American Math. Soc., vol. 33 (1927), pp. 81–89.

## SELECTED PAPERS OF THE 1929 SESSION OF THE SUMMER SCHOOL FOR ENGINEERING TEACHERS PRODUCTION DIVISION

The following papers were presented before the Mechanical Engineering Session of the Summer School for Engineering Teachers, held at Purdue University and at the Hawthorne, Illinois, plant of the Western Electric Company in 1929. They will shortly be reprinted in bulletin form as one of the series of Summer School Publications. Preceding numbers of the JOURNAL have included selections from the other divisions of the program. The present installment concludes the series of papers presented before the 1929 session of the School.

Additional papers of the Production Division of the program of the Summer School have been printed through the cooperation of the American Society of Mechanical Engineers in *Mechanical Engineering* and in the *Transactions* of that Society. These papers are available as Bulletin Number 10 of the Summer School series and can be secured from the office of the Director of the Summer School for Engineering Teachers, 99 Livingston Street, Brooklyn, N. Y.

# ORGANIZATION FOR PRODUCTION CONTROL*

By L. P. ALFORD

*Vice-President,* The Ronald Press Company

Anyone interested in this subject should study that epic of the last seven years, the Hoover Report on Recent Economic Changes. This great report traces the remarkable changes and developments that have taken place in the United States, especially since 1922. Some have referred to this period as a second industrial revolution, but this is rather too strong a characterization; it is merely a further development of forces long present in American industry.

In this period the production of manufactured goods has increased more than fifty per cent.; the productivity of the individual worker more than sixty per cent. There has been a considerable reduction in the actual number of men employed, in the working hours per man, and in unit prime costs. Plant equipment has increased about 29 per cent.; building space occupied about 27 per cent.; and primary horsepower about 22 per cent. Strange contrasts and contradictions apparently exist; but the pivotal change is in the increased productivity of the American worker.

These changes can be credited to the development of management; to industrial engineering in general; to production control in particular; and to the gain in knowledge of how to "get work past the point of the tool."

Modern production control started in the machine shop. It must be able to handle purely intermittent processes, as usually encountered there; purely continuous ones, as in petroleum and sugar refining; and those occupying a field between, as in the textile industries. A mass of variables must be dealt with, and the problem is extremely complex in

* Presented at the Summer School for Engineering Teachers, Purdue University, July 6, 1929.

detail, though fairly simple in principle. The following paragraphs are intended to outline some of the principles and practices of this most important phase of modern industry.

**Production control** may be defined as that system which, extending over a long period of time, controls the order of movement of the elements of a productive program in relation to each other and to the whole.

Kimball, in discussing the coordinating mechanism of production control, has written: "In certain production enterprises, however, there is, in addition, a much more difficult problem, namely, that of controlling production so that the required product shall be produced in the best and cheapest method; that it shall be of the required quality, and that it shall be produced in the required time."

**Principle of Production Control.** The highest efficiency in production is obtained by producing the required quantity of product, of the required quality, at the required time, by the best and cheapest method.

**Scope of production control** is difficult to establish because of varying conditions, but in general it may be said to include all the production activities from requisitioning raw materials for manufacture through the operation and process until the finished article is delivered to the store room or the shipping room.

Purchasing, storekeeping and their related activities may, or may not, be included, depending upon the organization arrangement and the location of the center of management. Involved here is the question: should the procurement, storage and delivery of raw materials be under the control of a single official, or should there be an independent purchasing agent and a storekeeper under the direction of the purchasing agent, or of the production manager who is responsible for using the materials? In principle the purchasing and storage functions should be separated to avoid corruption.

**Establishment of the Production Schedule.** The extent to which the probable demand for the product can be determined depends largely on the nature of the product, its demand, and effectiveness of the market forecasting methods.

A process industry manufacturing a highly standarized product can forecast its demand to a considerable degree. It uses

Past performance record,
Operating reports,
Budget estimate,
Statistical studies.

Highly intermittent assembly manufacturers cannot forecast the demand for its product to the same extent. Obviously the first industry can establish its production schedules more accurately than the latter, and thus secure more effective production control.

**Principal procedures in production control:**

(*a*) Production planning,
(*b*) Material procurement,
(*c*) Routing,
(*d*) Scheduling,
(*e*) Dispatching,
(*f*) Inspecting,
(*g*) Storing and handling work-in-process.

**Material Control.**

The functions of material control are:

(*a*) Investigate the demand,
(*b*) Requisition the material,
(*c*) Purchase the material,
(*d*) Receive and inspect incoming material,
(*e*) Store and protect the material,
(*f*) Distribute and handle material as required.

**Production Planning.** The function of production planning is to determine what shall be done and how it shall be done. It includes:

Analysis of manufacturing orders;
Determination of operation to be performed;
Determining sequence of jobs;
Fixing material requirements;
Determining tool and machine equipment;

Estimating process times;
Fixing time of commencing;
Fixing time of completion;
Checking estimated costs;
Originating the papers for production control.

**Material Procurement.** This function is performed by whoever is in charge of material control, which may or may not be the manager of production. It involves the delivery of material to the place where the first operation is to be performed, on time and in right quantity and quality.

**Routing.** Routing is determining the path or route along which work is to flow, or along which material is to move from operation to operation. It is a part of the function of planning. Involved are: "—the planning of where and by whom work shall be done; the determination of the path work shall follow, and the necessary sequence of operations. It forms a groundwork for most of the scheduling and dispatching functions of a planning department. The master schedule and manufacturing orders precede."

**Scheduling.** "The function of scheduling is to determine when, and at what rate, the various operations shall be performed and the events in the manufacture of a product shall occur." The scheduling clerk fixes the date when each operation of each part should start and finish. The determining of load of work ahead is also a part of scheduling.

**Dispatching** is guiding the execution of the plans. The dispatch clerks are concerned with the starting of the various operations on the orders in the shop. They forward the production papers to the shop and control the performance of the individual operations as regards schedule.

Some times another function called "preparation" is introduced. This concerns the removal of obstacles and avoidance of interruption in doing work. It checks the availability of materials, tools and equipment.

**Inspection** is the function of determining whether the product turned out is in keeping with the standards and specifications.

**Storing and Handling Work-in-Process.** This may be treated as an independent function, or it may be handled by the regular shop organization. Material handling has had an amazing development during the past few years, particularly along the line of mechanically pacing the speed of production. The automobile assembly chain is the striking example, but the same principle has been applied in all kinds of assembly industries. This development is one of the most striking since 1922.

The layout of plant and the arrangement of equipment have decided influence upon economy in production. So much is this so that new buildings, improved layouts and better equipment are constantly being sought for, and are continually being installed. It is estimated that one-half of the gain in physical production since 1922 can be attributed to betterment of these physical factors of production.

This element is closely associated with the handling of material previously referred to. The underlying principle has been stated as: "The greatest economy in progressing materials through a manufacturing plant is secured when the materials move a minimum distance in passing from operation to operation."

**Timekeeping** records yield the original information for making up the payroll, paying for labor, and for determining labor costs. The principal difficulty is to keep the sub-divisions of time reasonably accurate, for any errors in this information will be reflected in all the labor distributions, and in the costs. The determining of elapsed time is now very much handled by machine or recording devices, and so can be regarded as quite accurate.

**Cost analysis,** while not a part of production control, is nevertheless closely associated therewith, for the production records supply part of the basic information for the determination of costs. The paper work for production control has been developed to a high degree, and the literature on management is filled with charts and forms.

**Mechanical Aids for Production Control.** Much ingenuity has been displayed in developing mechanical aids for pro-

duction control. These are principally of two kinds, charts and diagrams, and control boards. The control boards can be quite properly thought of as elaborate charts and diagrams made of more substantial material than paper.

All of these devices aim at the common purpose of showing at any moment just how far production of a given item has progressed with telltale methods to flag jobs or orders which become delayed.

The best known system of charts for this purpose are the so-called Gantt charts developed by the late Henry L. Gantt. They plot actual performance against projected performance for definite intervals of time. The relationship between expectation and result is so close that these charts have a compelling urge to better performance. Without doubt they are the most widely used single management mechanism.

The kinds of Gantt charts applying to production are:

Machine Record Chart,
Man Record Chart,
Layout Chart,
Progress Chart,
Load Chart.

**Measure of Success in Production Control.** The literature of production control is filled with instances where production has been increased from 100 to 300 per cent. in the same interval of time, due to the improvement in the method of control. Associated with any such management installation are improvement in physical factors, layout of department and equipment, standardization of operations, improvement of tools, better supply of material, and others. It is therefore very difficult to assess against any one management function the results which it properly has brought. However, there is another measure of the success of a production control system, and that is the percentage of orders shipped on the dates promised. Reference to the principle of production control will show how closely this becomes a measure of result. Good practice indicates that from 85 to 95 per cent. of all orders can be shipped on time, provided a proper production control system is installed. A few cases are these:

| Company | Per cent. of Delivery Promises Kept |
|---|---|
| Sullivan Machine Company | 85 |
| New England Butt Company | 85 to 95 |
| Pioneer Box Company | 95 |
| American Metal Cup Company | 95* |
| Imperial Electric Company | Practically 100 |
| Ferracute Machine Company | 103 |

* In dull seasons this factor is nearly 100%.

# BASIC PRINCIPLES AND TRENDS IN PERSONNEL ADMINISTRATION *

By F. W. WILLARD

*Personnel Director*, Western Electric Company, Inc.

Much that has been written and said on this subject has suffered from the incubus of phrase making. I shall study to omit certain words and phrases which have in the past permeated such literature and had too large a place in the discussions of this phase of management. These words and these phrases have become an offense to an honest employer and the self-respecting worker.

The conventional treatment of the subject is to worship the "old days" of the small industry and its assumed idealistic relationship between a single owner-manager and an harmonious family of a few score or a few hundred "happy" workers. The acccepted procedure is to regret that all this Utopia has been destroyed by the aggregation of industrial units and the interposition of "hireling managers." Unfortunately, accurate data in support of such a thesis are wanting, and the author's material consists too frequently of a well-remembered exceptional example.

It is probably true that this supposed ideal industrial relationship in the seventeenth and eighteenth centuries resulted in the first large organized effort on the part of labor to defend itself against these patriarchal owner-managers. In the emergence of an industrial society out of an agrarian order, early in the last century in North America very quickly developed a defensive labor anti-toxin—against what? Not a few huge corporate employers, but a number of relatively small owner-managers.

Excepting the few kindly patriarchal owner-managers who have justly earned the praise accorded them and have inno-

* Delivered at the Summer School for Engineering Teachers, July 11, 1929.

cently cast a halo over the "old days," honest attempts to harmonize opposing interests of employer and worker really came with the advent of the large corporate employer and its "hireling managers." Wherever this attempt was honestly made, its motivation may be found in the desire and the necessity for continuous and sure corporate profit.

When labor became free, neither employers nor workers quickly changed their natures and their habits of thinking. The master and slave psychology lingered in both groups.

Paraphrasing recent remarks made by Mr. Sam Lewisohn:* Even the hardest-boiled employer of today would shudder at the recorded philosophy of kindly, serious economists of the seventeenth and eighteenth centuries, who asserted as an essential basis of economics that the free laborer must be kept near to starvation or he will have no incentive to work, and an industry will thereby be ruined.

It is unprofitable to try to analyze all social causes which have brought us to the present industrial status, but mention of a few obvious trends will help us better to understand the present problem.

1. All parties are exercising a more intelligent self-interest.
2. The advent of a large corporate employer has compelled the services of hired managers trained for large operations.
3. The transformation of industry by modern physical science concepts is compelling the services of *trained engineers* as hired managers.
4. The immortality of the corporate employer compels a policy of perpetuity insurance.
5. The restraint of a rampant individualism is compelled by the greater material rewards flowing from co-operation.

The question subconscious in the minds of every responsible employer today is: "Does management know now where it

* *American Labor Legislation Review*, page 51, March, 1928, "Labor Legislation and the Business Mind," Sam Lewisohn.

is going?"—and the honest answer is "No"; but it must be qualified by the statement that neither does the engineering profession know where it is going. As its fundamentals are subject to change as the frontiers of knowledge are pushed back; as its criteria are more and more applied to the problems of management-employee relations; the path is cleared ahead at least for some distance for those who can see.

So far as I can discern, industry is fortunate at the present moment in having a trained profession from which to draw its hired managers, a profession which has not yet been infected by cerebral sclerosis.

One of the serious criticisms of industrial managers today is that their individual policies, if any, are built upon an unstable foundation of expediency. I think that is a favorable criticism, and chiefly on that account the prognosis for future industrial management is good. Approaching his problem with the unfrozen intellect of an engineer, the industrial manager is going to plan ahead just so far as the facts at his command will insure his objectives. If he doesn't do that, of course he's a failure. This is all that the word expediency means as applied to management policies. Those in industrial management today who have not approached the problem in this attitude have had unfortunate experiences in not a few instances, and I think that some who believe that they have found the final answer are due for disappointment.

Engineers as a group are not, of course, free from the temptation to extrapolate their knowledge far into the future and confidently assume that they can plan their engineering structures and processes thereon; but those engineers who have really qualified as competent industrial managers have had their professional enthusiasm under a practical control. With proper caution they do plan ahead. This is what expedience means to the engineer-manager.

All of these preliminary statements are made to emphasize the fact that however enthusiastic individuals today may be over sure-fire, sure-cure methods of personnel management, there are no such things. In ten, twenty, or thirty years hence, if any of us are living, we shall probably be amazed at

our present inexperience and stupidity. I hope that those who hear or read this will keep this confession in mind when considering the specific discussion which follows.

The problem of management of people in a profit-making industrial enterprise comprehends two main divisions:

I. Compensation.
II. Working Environment.

Because some of the subdivisions overlap or are closely inter-related, most published treatises do not clearly delineate these two main divisions and there results in the current literature much distortion of emphasis depending upon the author's experience and interest.

The several subdivisions are too frequently treated as unrelated problems and the answers given with finality in the text.

There are no final solutions in sight. All are experimental. When our distinguished President of the United States said in accepting the candidacy last year that agriculture is not an industry but a mode of life, he could as truthfully have added that employment in organized industry is a mode of life and as such cannot be restrained by dogmatic finalities.

All the principles of management applied today are experiments and the only legitimate restraint upon such experimentation *is the necessity* of protecting the industry from insolvency.

## Compensation

Industrial enterprises are today built upon the principle of free labor which implies a compensation to the worker by and large in proportion to what he is able to contribute socially through the organized enterprise.

It appears to be necessary then that his compensation be measured and paid in proportion to his contribution. That sounds simpler than it is, because of the necessary coordination of effort.

To go back to a pre-mechanical classic example: the old-time shoemaker, when he located in a sufficiently large social unit, could supply all his needs of life by devoting his entire

time to making shoes. If he enjoyed a monopoly in his group he lived well; if he had to meet competition he lived well or poorly, according to his skill; but *he carried all the risks.* His social adjustment was simple. He understood it thoroughly, however ignorant of classical economics he may have been.

Now the worker who tends a machine which only blanks the sole of a shoe can't by any reasonable exercise of wit follow all the devious economic paths by which the watching of that blanking press brings ready baked bread to his kitchen door; nor can he even imagine how many other workers all over the world are necessary links in that life chain.

He benefits, however, by a relatively greater economic stability than his predecessor who made the whole shoe by hand, but he doesn't know it and of course blames his employer when he thinks that his wage is not adequate.

The employer is equally puzzled for he can't figure how much he can afford to pay for watching the blanking press except by its proportionate share of the cost of the finished shoe which leaves him a profit in his competitive market.

So he does the next best thing. He tries to determine the average current wage for similar labor in the community and pays the man that wage which he believes will keep him on the job.

Practically that is the wage which all industrial enterprises pay, plus whatever premium an incentive method can stimulate in the more competent and industrious workers.

Therefore, the wage base of a task in any community is in the last analysis what workers in that community can command for that task. It may be low because of worker competition or high because of scarcity of such workers, or it may be temporarily controlled by combination of workers. I say temporarily advisedly, because union pressure on any class of wage bases is eventually modified by competition of one sort or another. Over periods of time no kind of artificial control of wages by combination of workers or by statute operates, for the same fundamental reason that artificial control of commodity prices by law or monopoly ultimately fails.

Summarizing then, the wage level of any community is controlled sometimes temporarily by a strategic bargaining power between the contracting parties, more permanently by current supply and demand, and finally by the social value of the work done.

The relation between current wages for the different degrees of skill in labor is finally determined by the social values of the different kinds of labor, though temporarily these relationships are distorted by variable supply and demand in the several grades. For example, early in the World War a general shortage of so-called unskilled or heavy labor forced an advance of its wage base out of relation to some of the crafts. The adjustment came slowly but it came, and the old approximate ratios prevailed.

Mechanization is blamed for much social distress. This is not without reason in certain spots, but it would seem that the good it has brought to the worker by the provision of new work and greater stabilization has more than offset the injury. Its overall social benefit has not been reckoned nor appreciated. By it great groups of people of limited mental and manual skill have found a respectable and dependable living where they were before partial or total social dependents. It does not make morons but helps many moronic individuals to a decent living. Contrary to the general belief it has stimulated the demand for some old and many new skilled crafts.

Is the competitive wage the whole answer to this paramount problem of management? I dare say some employers still believe so, but the practices of the more enlightened indicate a negative answer.

The reason seems clear. Orderly accounting of costs revealed to the employer many elements in the labor item which he didn't know existed. He found that the steady self-respecting worker was the most economical kind; that such workers by and large were those who were free from anxiety about their economic status. What could he do to mitigate such anxiety? What does the average man worry about most? The answer is about like this.

1. Adequacy of income.
2. Continuity of income.
3. Protection of his dependents.
4. Protection for his old age.

Taking them in order, if a man is to do his best and therefore be most profitable to his employer that employer must think up ways and means of paying him *the most the business will stand, not the least.* Manifestly, if the fellow comes to feel that he is getting all the money he can expect to get in any other kind of employment he will not usually stew about his wages. To feel that way he must be convinced that his job gives him the opportunity to use all his abilities. *Opportunity is then the key.*

It is used by enlightened employers in the following practical ways:

1. Training for the job.
2. Incentive wage plans.
3. Promotion when and as qualified.

I should like to discuss all of these, but each requires a volume for even an effective outline of methods tried. It should be observed that the second (wage incentives) is still in an experimental stage. Many plans are used with more or less success, all of which are based upon more or less exact and objective measurement of work done.

The simplest and most direct method of individual straight piece work has been most successful where the employer has had the intelligence to be honest in its administration and has been able to stabilize its objectivity by exact engineering of process. Too much emphasis cannot be placed here. *A rate for a measured or measurable task becomes a moral if not a legal contract of employment, and the employer who does not keep such a covenant pays for his infidelity.* No less does he pay if his process engineering is so poorly done that the measure of the task is inaccurate and the best method of doing it is not determined before the rate is set.

But you say this is impossible. A better way is always possible. The best way of doing a task at any given stage in

the art of manufacture is always a practicable objective. New art of manufacturing results from the work of engineering development and when it can be shown to be profitable, fidelity to principle requires the employer to enter *a new contract which will not diminish the compensation for the same labor effort.* You will say that this dodges the issue of the effects of mechanization on the number of people employed. The intelligent management is not dodging it but is seeking honestly the means for the necessary temporary adjustments.

There are increasing in number so-called profit sharing plans which are, generally speaking, incentive wage methods whereby the payment of the incentive is to some extent determined by the current prosperity of the enterprise. Such payments are usually made annually at a time when the year's results become known.

**Continuity of Income.** Continuity of income may be jeopardized by:

1. Instability of the enterprise.
2. Seasonal activity of the enterprise.
3. Sickness and accident disability of the worker.

Manifestly the employer and the employee have a common interest in the stability of the employing enterprise. Here is the common ground on which the two supposedly opposing forces can and should meet and cooperate. The responsibility, however, is on management. *No amount of employee good-will and cooperation will compensate for the blunders of stupid business management.* The business must pay and pay continuously, and to do this it must plough a liberal fraction of its profits back into its methods. In these days it will quickly find itself defunct unless it can and will devote some of its resources to research and development. There are plenty of industrial wrecks strewing the last two decades because of neglect of this principle of management.

Much is said about stabilization of industrial employment by smoothing out the peaks and valleys of economic progression. Doubtless with greater experience and foresight something can be done but it is not now apparent how such fluc-

tuations can be entirely removed. Their sharp severity can and should be softened, but a moderate periodicity may be more beneficial than otherwise. It surely makes for more conservative financial management and definitely affords a healthy prophylaxis of working forces.

Seasonal instability is an admittedly bad condition for the economic stability of workers. Not a few enterprises have bravely tackled this problem and some have definitely solved it by development of related lines of product which can keep workers and equipment occupied at a reasonably steady level. Building operations were conceived to be hopelessly seasonable, but persistent attack on methods and materials has routed this particular kind of fatalism.

Sickness and accident disability as the most serious source of discontinuity of income to the worker has been successfully attacked.

By careful study of mechanical preventives, and what is more important, patient and continuous education of workers in their own interest, accidents in manufacturing and railroad transportation industries have been reduced in severity and frequency more than thirty per cent. in twenty years. It can be truthfully said that in the average factory environment today a worker is much safer from accident than on the street or in his own home.

The success of this management effort has encouraged forward-looking managers to spend some corporate funds on the education of workers in the proved rules of health. It is too early to say what the results will be, but the effort is at least logical and intelligent.

The provision of healthful working environment has been one of the outstanding characteristics of industrial management in the past two decades. The wise ones have not been forced by legislation. The foolish ones nowadays pay the price in their inability to attract the good workers of the community into their factories.

The law has admittedly forced the correction of some of the worst conditions, but it has signally failed to enforce a high

standard of factory sanitation. Far-sighted employers have done that.

The law has, however, clearly established the responsibility of the employer for accident disability and occupational diseases, and with somewhat more intelligence than is usually found in "popular" government, established machinery of adjudication which dispenses a much more effective justice than is possible in our ordinary courts.

Not many employers took kindly to this "interference," as they termed it, when the first compensation acts were introduced, but the wise ones soon realized its advantages and went considerably further in the assumption of responsibility not only for disabling accidents, but also for sickness disability not arising out of conditions of employment. Thus today the enlightened employer finds it profitable to protect his workers against discontinuity of income on account of sickness. This is done by both mutual and non-contributory methods.

**Payment for Absenteeism.** Another important part of labor compensation is payment for absenteeism not contemplated in those plans which provide for sickness disability and obsolescence.

Payment for such absenteeism is equivalent to additional compensation, though I fear that few workers so regard it.

Here past practices have been inconsistent and to some extent illogical in that the lowest grade of worker enjoyed little or no protection. The white collar worker or office worker was given preferred treatment because perhaps he was at an earlier date classed as a brain worker and consequently harder to get and keep.

In the last decade there has been an awakening to the unfairness of such discrimination between these two classes of essentially the same social levels.

Methods vary all the way from a long service eligibility condition to the most enlightened policy of granting vacations in preparation for the coming year's work (a strictly health measure) to all employees on the payroll except for a very brief novitiate. A few employers pay their hourly or day workers for regular holidays the same as the salaried em-

ployees. Some employing enterprises have a liberal policy toward salaried employees who have established their true value in the payment of salaries for absences for personal reasons. Here practices vary widely. Usually a very limited group of valuable employees enjoy this added compensation.

The most enlightened employing industries pay regular wages for absences on account of civil or military duty, and do not deduct the compensation received by the employee for that service.

Altogether the wages paid for absenteeism are an appreciable part of the total annual compensation. To 15,000 salaried employees one company thus paid in 1928 $1,750,000, or about $117 per person.

A corporate employer doing business in more than one community is compelled in the interest of sound organization development to transfer employees from one locality to another. These employees are usually key men and more often than not carry family responsibilities. It is a serious matter to uproot and transplant a whole family. The employee morale will not easily resist the demoralization of the family because of the tearing up of its social roots.

Therefore it is the part of wisdom to be liberal in the paying of *all* expenses incident to such necessary transfers of personnel. The wise employer today pays all direct moving expenses of the employee and immediate family and in addition makes a liberal expense allowance to him to establish a home in the new locality.

Thus sketchily have I tried to outline some of the more practical ways by which intelligent employers have tried to relieve the workers' worry in respect to continuity of income.

**Protection of Dependents.** To protect his dependents the worker wishes to provide an estate. He can do this by saving or by insurance or both. Of course this implies adequacy and continuity of income. Under these conditions the employer who builds for the future assumes certain responsibilities. He provides death benefits either wholly or on a contributory basis. He provides group insurance usually on a contributory basis,

and if he is wise he undertakes to help his employees to save and invest wisely by providing means for them to save regularly through payroll deduction plans, investing the money for them in sound securities. These instrumentalities are not to be confused with so-called profit-sharing plans which include stock ownership in the employing enterprise. For clarity I will not refer to profit sharing except as a part of the annual compensation. While it is true that many stock purchase plans carry an incentive in the form of favorable purchase price or bonus, they are essentially means of helping the worker to save his own money.

Credit unions and building and loan associations organized by the workers and assisted or encouraged by the employer are other forms of thrift facilities.

Not a few employers offer payroll deduction service for accumulating savings bank accounts.

Others assist employees to purchase standard life insurance at lowest possible premium rates by weekly or monthly deductions from pay.

The death benefit in either a contributory or non-contributory plan is usually only nominal in that it does not constitute life insurance adequate for the employee's dependents. In most plans death benefits do not exceed $2,000.

The problem of life insurance for the worker is yet to be solved. It cannot be discussed here at length.

Outside of formal plans a few employers provide relief funds for their employees to help them out of emergencies where they would otherwise be unable to get help. These measures may take the form of loans with or without interest, actual gifts of money or equivalent, or financial advice in the ordering of their personal affairs if they seek such service.

The hired managers of present day industry have, as you see, treated this business of the worker's compensation from a different viewpoint than the old owner-manager. They have tried to get away from that lingering master and slave psychology.

I have distinguished between so-called profit sharing and stock purchasing. Some stock purchase plans do have special

terms and features favoring the employee to an extent to put them in the class of profit-sharing plans. The plans are various and require a volume for complete understanding of their character and details. The bibliography which I have prepared will help you quickly to lay hands on the answers to your questions.

Education in thrift—for that is what this all means—is to make the worker a consciously independent economic unit of society, and employing industries are providing it because such persons are the most profitable to have about the works.

**Provision for Old Age.** Provision for old age sooner or later becomes the worry of more than 90 per cent. of all the people of our country.

How does the forward-looking employer try to mitigate it? It has been the feature of some of the earliest attempts by American corporate managements to meet their personnel problems intelligently.

Prince Otto von Bismarck grasped the significance of it to an industrial state when he forced statutes through the German Reichstag way back in the eighties of the last century, providing among other things state old age insurance to be paid partly from direct property taxation and partly from specific taxes on industry. Ludwig gives him no credit for humanitarian motives, accusing him of seizing upon it as a political back-fire against the opposition of his own caste. However, about or before that time employers in this country were making retirement compensation plans for their employees.

The problem is not solved today. Plans were started without actuarial study of the ultimate liability to be accrued. Those industries which prospered were able to meet these liabilities currently as they became due, but not all industries prospered and those which had assumed such serious obligations and failed to be able to meet them brought not a little discredit on what was an honest attempt to meet a fundamental problem.

There is more caution now. Some employers still have noncontributory plans and are providing for their future obliga-

tions by funding future accruals in trust by annual charges to current expenses, using the best actuarial methods for estimating such accruals. Some have adopted contributory plans which divide the cost between employer and employee. The contributory plan is gaining in favor. Few corporations today are launching new plans on a non-contributory basis.

I have given the most space to the problems of compensation for it comprehends most of the others.

**Continuity of Employment.** While this has been treated in its relation to compensation there are some features of it under current public discussion. Much noise is being made these days about the displacement of workers by mechanization of industry. It is going on. Probably one of the most revolutionary movements in industry is upon us but we cannot see it clearly because we are in the middle of it.

Naturally, cause and effect are confused hopelessly in the minds of all involved. Even scientific economists and engineers do not see the problem clearly, much less the answer. Politicians, of course, have muddied the waters so that a solution is more difficult. President Hoover's Committee on Recent Economic Changes has just made its report which is indicated as the most authoritative work yet done. After we have had time to study it thoroughly we may know more about practical solutions.

A part of this problem resulting from improved management technique and the consolidation of enterprises is the displacement of older employees. It is not a new social problem and it may be that it is being now over-emphasized, but it must be met. There is much confused thinking about it because facts, as usual, are elusive. Some social workers finding it much easier to generalize than to labor for the facts are stirring up some false issues. I suggest this thought:

> If stabilized enterprises will select and train their workers carefully, and retain the effectives through their productive years, pay them adequately, help them to save and provide a retiring allowance, the solution will be nearer than some now believe.

Industry is becoming socially conscious. It is becoming more apparent that as society changes from a predominantly agrarian to an industrial status, the cost of providing for the aged, the defective and the indigent becomes a very practical problem to industry which bears an increasingly larger portion of the taxes. In self-defense then, industrial managers will not seek methods which may transfer that cost to public taxes. They can do it cheaper and incidentally save the dignity of the superannuated and unfortunate among its workers.

### Working Environment

Today the employing industry which does not do all in its power to make the environment of the worker while at work as healthful and pleasant as possible is quite unintelligent. It soon finds that it can't compete in the local market for labor.

Good sanitation, clean buildings, good light, good drinking water, are not debatable.

Working hours which do not exhaust the workers' energy, safe equipment and methods are taken for granted. The more advanced employers believe that some attention even to the esthetics of the workers' surroundings is profitable.

There is a widespread conviction that social and recreational facilities provided at corporate expense are fully justifiable. As a result you see in many industries recreation buildings, athletic fields, and social organizations of many sorts encouraged and subsidized, and out-of-hour educational facilities provided.

These measures have brought results unquestionably. People who have the opportunity to play together will work together in greater harmony; and any industry today is a cooperative enterprise.

The errors in this direction have been an assumption on the part of not a few employers that excellent physical working environment with extensive recreational facilities and social organizations of workers *are the essentials* of personnel management. All the emphasis is placed on this phase of management so far as the worker is concerned.

Obviously they fail. The general employee is no fool. Of course he'll take what is given to him if it suits him. A few obsequious ones will dissimulate their dissatisfaction but most of them quite properly will not accept such practices in lieu of fair and continuous compensation, intelligent and friendly supervision, efficient management, and self-determination.

The wise employer today leaves the determination and management of out-of-hour educational, social and recreational activities of his employees very largely to them. I believe the time is coming when it will generally be left entirely to the employees and paid for by them.

Certainly the forward-looking management is today concentrating its effort and money on: First, the development of the man by adequate job training, so that he may make the most of his faculties; second, the training and development of supervisory employees so that the purpose of management may be correctly interpreted to the worker.

Supervisory training is the order of the day. It takes on many forms and is largely experimental. In the not distant past, and in many industries today, about all the management did to train the supervisor was to select the individual on the basis of his technical or trade knowledge and proven capacity to drive people to work. Then it left him alone except to demand production from him. How he got it was of little concern. That is no longer effective under the spur of severe competition.

The objective of most supervisory training methods today is to teach more or less effectively how to get the good will and cooperation of the worker.

It may seem simple, but it is not when you realize that most managers are not skilled teachers; that they came by their success, whatever it is, by the time honored method of drive. Their example is their most effective instrument of teaching their subordinate supervisors, and while sincerely professing faith in the new methods of cooperation, that example is very bad. They may teach by lectures, by conferences, by texts, by preachments, but unless they first determine how the worker actually responds to his supervision their efforts are vain.

I believe a new technique is coming in this matter of training supervisors and that it will be based on what the worker thinks is a good supervisor; not on what the boss may think about it.

Certainly Mr. Pennock's experiments at the Hawthorne Works point very definitely to a new and better technique.

Manifestly, the most important condition of working environment is the technique of the immediate supervisory employees. They may be skillful in sensing the feelings and aspirations of the workers entrusted to their supervision; they may be sensitive to the worker's frame of mind and truly reflect it to the higher supervisors; but in most cases they do not, and the process of education is a slow one. Precept, as taught in many of our supervisory conferences and classrooms, serves inadequately in lieu of experience for the purposes of this education.

The commonest remarks in conferences of supervisory employees, both high and low, are positive statements made about what the worker thinks; how he feels about the management and whether he is happy or not. These statements may sometimes be made by persons who really have a technique and know that they are speaking the truth; but in most cases they are only guesses. Even in modern industry, with all the attempts that have been made to combine the workers' interest with that of the industry itself, the suspicions and inhibitions of the old master and slave psychology which we have all inherited still support a barrier between the general worker and his supervisor which few supervisors succeed in breaking down to the extent of getting a free and frank expression of the worker's viewpoint.

Emphasizing again that the new technique must be built from the standpoint of the worker's idea of what good supervision is and not from the standpoint of the management, it may be possible so to indoctrinate future generations of front-line supervisors with a technique of meriting the confidence of those under their supervision that these particular inhibitions may be ultimately eliminated.

The past two decades have seen a great deal of attention

given to this subject on the part of management, and that attention has, it seems to me, been directed along lines which are admittedly practical and have admittedly produced useful results, but are fundamentally unsound because they are built on the idea of an inevitable conflict of interest between the general worker and the management. It isn't unnatural. It is of course our old familiar heritage, carried into our day by the trade union movement.

Modern management, if it is intelligent, sincerely wishes to know what the worker thinks, if anything. The trade union movement gave it, by organization on the basis of inevitable conflicts of interest. The representative of the trade union was no better, so far as his relation to the worker was concerned, and in my judgment in many instances was not so effective a spokesman for the worker, as the front-line supervisor in a modern industry can be today. He may or may not be chosen by the worker to represent him. Theoretically he is. If he is honest, as many are, and intelligently tries to perform his duties as the representative of the worker, he is able to accomplish some benefits. He has to do this, however, by means of compromise with the employing managements and those compromises generally are the result of a battle of wits, seldom admitting any common interest.

The defect in this plan is plainly recognized by the present labor leadership in this country, which has in recent years made a number of attempts to eliminate the age-old inhibition of conflicting interests and to extend a hand of cooperation to the employing groups. It is too early yet to say how successful they will be. Manifestly, organized labor is operating under difficulties within its own organization because the process of education through the rank and file of their trade groups is just as difficult as it is among other groups of similar intellectual levels; and they have not, of course, complete control over the responsible officers of their several affiliated associations, some of whom are clearly not converted to the idea of cooperation versus conflict.

The earlier resistance to trade unionism on the part of managers was of the purely belligerent type, but early in this cen-

tury some industrial managers correctly conceived the idea that such methods could result only in loss to all parties concerned, and undertook to build a different kind of back-fire against trade unionism.

This was the beginning of what is today known as the employee representation movement. In speaking of it in these terms I wish only to uncover the facts of the situation; I do not impute insincere methods to most of the managers who adopted this movement. Some admittedly did it without sincerity and with a definite purpose of breaking up trade union organizations in so far as their employees were concerned. Others who were not facing a serious situation in respect of trade union organizations started similar movements in all sincerity and good faith for the purpose of accomplishing the one great objective of finding out what the worker actually thinks so that his environment may be set up on the best practical basis to inspire his cooperation.

In so far as this latter motive dominated, many of these plans have accomplished certain very definite results; so much so that the movement will unquestionably go down in the history of the technique of industrial management as a definite forward step. However, it still has its foundation in the old inhibitions of the master and slave relationship. It is predicated upon a conflict of interest. In that respect it doesn't differ in principle from the trade union relationship.

It has of course been violently attacked by the trade union organizations and there have been enough concrete cases of insincere operation of the plan to give the trade union leaders very excellent ammunition with which to fight it.

Where it has been adopted with frank and sincere motives the benefits flowing from it have been sufficient to extend the practice. I believe that today there are well over a thousand different enterprises having formal plans of this kind varying only in detail of method.

As an instrumentality for determining what is on the worker's mind it may not be better than the new trade union method offered to American employers by the trade union leaders. In some instances it seems to be definitely better, in

that it reduces the element of conflict and definitely increases the degree of cooperation. However, its principle is the same as that of the trade union method. It involves the selection of a representative on the part of a group of employees. This representative may or may not be competent to speak for those employees. There is good reason to believe that such selection, however wisely it may be made, is more likely to be determined on the ability of the representative to be a good negotiator than upon his ability truly to reflect the thought and aspiration of his constituents.

I believe management must go a step farther and attempt to break down completely the idea of a conflict of interest. To do this it must really know what the employee thinks. Management by all the scientific means at its command may determine what is a fair wage and conscientiously believe that it has done a good job; but a fair wage is in the last analysis that which satisfies the employee. That doesn't mean that the employee's satisfaction is unlimited with respect to wages. There is a substantial body of common sense among workers which tells them about when they are receiving compensation in proportion to what they give, and their superficial grumblings about their wages may not indicate real dissatisfaction therewith.

The management may think that it has the most expert and beneficient supervision, but until it knows what the employee really thinks about that supervision it is working in darkness. Therefore the problem of the present day is to find out what the worker thinks, what are the worker's satisfactions and aspirations, and to set up management policies that will synchronize with the worker's viewpoint and compel thereby his cooperation.

There is unquestionably an entirely new field in which to work, new technique to be developed, and new profits to be uncovered for all parties to the undertaking.

As mentioned before, Mr. Pennock at the Hawthorne Works is conducting extensive experiments on small groups of employees under controlled conditions. These experiments are primarily undertaken to define in accurate engineering terms

the optimum environment for the worker; but the by-products of these experiments seem to be even greater than the main products which were his original objective. These by-products seem to point to a practical technique for knowing the kind of environment which will compel the cooperation of the worker.

All of the results to date indicate that what we have guessed at and theorized about for many years is the principal need, namely an intelligent front-line supervisory technique.

I have a feeling that when we know more about the worker, have a more frank expression from him of his views on effective and ineffective management, we will be in a much better position to evaluate all of the instrumentalities of management which we have been discussing and put them in their proper relation to each other.

The social implications of the results of elimination of the master and servant psychology are interesting as a matter of speculation. It is not profitable, however, to enter this field. The things about which I have been talking may have seemed to be somewhat visionary, but I believe that they are rooted in practical application of our best knowledge of the behavior of human beings, considering them not as a mass but as a group of individuals, a large majority of whom always react normally and rationally, and a small minority of whom always react irrationally. Then the problem of management is to set up an environment which will command the cooperation of the rational and cure a substantial number of the irrational.

## Summary

The basic principles are:

I. A total compensation which shall meet not merely the competition of any given time or place, but the reasonable aspirations of the worker.

II. *An Opportunity.*

III. A working environment which makes the worker comfortable and at ease:

(*a*) By safe and sanitary and pleasant factory plant;

(*b*) By supervision which meets the individual worker understandingly and inspires his confidence.

# PURPOSE AND SCOPE OF SHOP COURSES *

By O. W. BOSTON

*Professor of Shop Practice,* University of Michigan

In former days, shop courses were admittedly of the manual training type. For what reason, there appears to be no clear explanation. The instructors who gave these courses were selected for their skill rather than for their education. This, no doubt, accounts for the small progress made in the art of teaching shop practice up to the last few years.

There are many secondary schools giving courses in shop practice, the object of which is to teach trades. Such courses have, in some instances, been more or less copied by engineering schools. Some engineering schools actually give trade courses which are taught by those who also teach engineering students. This seems rather dangerous because of the liability of the two courses gradually to merge. We have this problem at the University of Michigan. A special course in shop practice is given to first year dental students. It is designed primarily to develop manual dexterity. Constant watch is necessary to keep the instructors from teaching too much engineering to the dental students or too much mere skill to the engineers. Of late years many of the trade courses have either been improved or omitted from engineering curricula altogether.

The value of shop courses in any curriculum depends on the purpose of the curriculum and the nature of the shop courses. So many factors are involved that what might be considered a good course in one school may be out of place in another. The working organization of the department in which shop practice is taught may also influence tremendously the results obtained. The initiative of the members of the staff and their ability to change their courses in accordance with new ideas, better methods, or better practice is of importance.

* Presented at the Summer School for Engineering Teachers, Purdue University, July 1, 1929.

Some features to consider in the preparation of shop courses for a curriculum, are:

1. The object of the curriculum.
2. The general purposes of the shop courses.
3. The phases of shop practice to be covered.
4. The total time to be devoted to required shop courses for each curriculum.
5. The time allotted to each phase or course.
6. The years during which each course should be given.
7. The purpose of each specific shop course.
8. The content of each course and the relation of the various subjects covered to other courses such as drawing, design, metallurgy, metallography, engineering mechanics, etc.
9. The method of conducting the course, such as the amount and nature of the class work compared to the amount and nature of the laboratory work.
10. The type of teachers and assistants in direct charge of the instruction and the influence of the department head.
11. The buildings and equipment available for shop practice instruction.

In discussing these features, it is assumed that the object of the curriculum, expressed briefly, is to train the student to assume positions of trust and responsibility in the engineering and industrial world. To do this, he must be trained in the fundamentals of the sciences and, if possible, he should have an acquaintance with the principles of management and with languages, history, economics, and other humanities. Skill in any line of endeavor may be an asset, but the larger organizations primarily desire graduates who are trained to think clearly and who have a well-rounded education.

The general purpose of shop courses is, then, to acquaint the student first-hand with materials, the technique of working them, and the economic phases of production. Various types of materials, chiefly metals, should be studied as to their composition, production and treatments, methods of fabrication, or process of conversion into finished products, and the influence of these factors on design. Whether in job or mass production, the part is usually made of a material specified to

possess needed qualities. The processes by which that part should be formed, treated, built up, or worked may prohibit the use of the most desirable material so that a compromise is made and one less suited is substituted.

The student should understand the economic advantage of using one process instead of another which might make it desirable to use a material less suitable because of its properties but better adapted to manufacture. If a part is to be made of steel, for example, it may be forged, cast, rolled, or drawn. The part may, however, be of steel, cast iron, malleable iron, brass, bronze, aluminum, or any one of the other hundreds of alloys, each having an indicated best method of forming or working. The part should also be so designed for material and shape that it is adapted to manufacture. These principles should be studied in the classroom and applied, whenever possible, by the student himself in the laboratory. In this way, a certain amount of skill is acquired, although this is a secondary consideration. Shop laboratories should serve to acquaint students with equipment and accessories in the same manner as do the mechanical, electrical, physical, or chemical laboratories. As many as possible of the processes used in modern metal industries should be demonstrated. If feasible, this should be supplemented by trips to nearby plants. The actual operation of machines of various types seems desirable. This should be done to a moderate extent, not for the purpose of developing skilled operators, but rather to illustrate the technique and sequence of operations and to acquaint the student in general with machinery, tools, and set-ups commonly used. Many of the elements of management may also be illustrated to advantage along with these various operations.

Table 1 shows a summary of replies by a number of typical engineering schools to the question "What are the general purposes of shop courses? Is the object to develop skill; to provide machine operation; to acquaint students with materials, equipment, processes; or what?" It is seen that the tendency is not to teach skill as a primary object, but rather to teach principles and methods.

The phases of shop practice to be covered should be of such a nature that the student is given a chance to learn first-hand the various properties and uses of materials. This naturally brings shop courses of a desired nature under four main headings:

1. Woodworking.
2. Working and Treating of Wrought Iron and Steel.
3. Cast Metals.
4. The Machining of Metals.

TABLE 1

A Summary of Replies to the Question, "What Are the General Purposes of Shop Courses?"

| College | General Purposes of Shop Courses |
|---|---|
| Cornell..... | To illustrate economic methods of production. To acquaint students with materials and equipment by actual contact, and the operation of as many standard machines as possible, demonstration of labor-saving devices and specialized machines and automatics. |
| Michigan..... | Principles underlying the working and treating of materials; technique of processes; relation between processes, materials, and designs; acquaintance with equipment and economic factors in production. |
| Minnesota..... | Materials, equipment, and processes. Some operation. |
| Missouri..... | Acquaintance with tools, machines, materials. Little stress on skill owing to shortness of time. |
| Wisconsin..... | To develop what skill can be developed, and all of the above. |
| Ohio State..... | To acquaint the student with what can be done; how it can be done; the machines, tools, and methods used in the doing; and the nomenclature of the subject. This, of course, applies to the shaping of wood and metals to some useful purpose. |
| Penn. State..... | Teach Production Methods. |
| Iowa Univ..... | To acquaint students with materials, equipment, and processes. |

Additional courses may be offered dealing with advanced work in these subjects or on the design and construction of

## TABLE 2

REQUIRED SHOP COURSES OFFERED BY VARIOUS SCHOOLS, SHOWING THE STUDENTS TAKING THEM, THE YEAR THE COURSE IS REGULARLY TAKEN, AND THE HOURS OF THE COURSE EXPRESSED AS A FUNCTION OF THE TOTAL HOURS OR UNITS REQUIRED FOR GRADUATION

| College | Course | Students | Year Offered | Units over Total |
|---|---|---|---|---|
| Cornell ..... | Pattern Making..... | M, E, C | 1 | 2/140 |
| | Introductory Lab..... | M, E, C | 1 | 2/140 |
| | Foundry..... | M, E | 2 | 2/140 |
| | Machine Work..... | E | 3 | 2/140 |
| | Machine Work..... | M | 3 | 3/140 |
| Illinois..... | Foundry and Pattern Lab.. | M, E, General | 2 | 3/142 |
| | Machine Lab..... | M, E, General | 3 | 3/142 |
| | Machine Lab..... | M | 3 | 3/142 |
| | Heat Treatment of Metals. | M | 4 | 3/142 |
| Michigan.... | Metal Working and Treating..... | All | 1 | 2/140 |
| | Foundry..... | M | 3 or 4 | 4/140 |
| | Machine Shop..... | M. and A.E. | 3 or 4 | 4/140 |
| Minnesota... | Pattern..... | M, C, E, P.D. | 1 | 2/204 |
| | Foundry..... | M, C, E, P.D., Ch. | 1 | 2/204 |
| | Forge..... | M, C, E, P.D., Ch. | 1 | 2/204 |
| | Machine..... | Ch., C | 1 | 2/204 |
| | Machine..... | E | 2 | 2/204 |
| | Machine..... | M | 2 | 3/204 |
| | Machine..... | M | 2 | 3/204 |
| Missouri.... | Pattern Making..... | M, E, C | 1 | 2/120 |
| | Forge and Machine Shop... | M, C, E, Ch. | 1 | 2/120 |
| | Foundry Practice..... | M | 4 | 4/120 |
| Ohio State... | Foundry..... | M, I | 2 | 3/235 |
| | Advance Foundry..... | I | 3 | 2/235 |
| | Metal Bench Work..... | M, I | 2 | 2/235 |
| | Millwrighting..... | M, I | 2 | 2/235 |
| | Pattern Making..... | M, I, E, Ch. | 1 | 3/235 |
| | Forge and Heat..... | M, I | 1 | 3/235 |
| | Forge and Sheet Metal Work..... | E, Ch. | 1 | 3/235 |
| | Elementary Machine Work | M, I, E | 2 | 3/235 |
| | Advance Machine Work... | M, I, E | 2 | 3/235 |
| | Advance Machine Work... | I | 3 | 3/235 |

| College | Course | Students | Year Offered | Units over Total |
|---|---|---|---|---|
| Wisconsin... | Pattern Making, Welding, Forge, and Bench..... | M, E, Ch. | 1 | 2/140 |
| | Machine Work..... | M, E, Ch | 1 and 2 | 2/140 |
| | Tool Making..... | M | 2 | 2/140 |
| | Shop Projects..... | M | 3 | 2/140 |
| | Advance Pattern..... | | | |
| | Problems..... | M | 4 | 1/140 |
| | Foundry..... | M | 3 | 1/140 |
| Iowa Univ... | Mfg. Processes..... | M | 2 | 5/138 |
| | Mfg. Processes..... | E | 2 | 3/138 |
| | Mfg. Processes..... | Ch. | 2 | 3/138 |
| | Prod. Methods..... | M | 4 | 2/138 |
| Penn State.. | Joinery..... | Archit. | 1 | 1/152 |
| | Wood Products..... | | | |
| | Production ..... | M, I, E, E.C. | 1 and 2 | 1/152 |
| | Foundry..... | M, I, E, E.C. | 1 and 2 | 1/152 |
| | Pattern Making..... | M, I, E | 1 and 2 | 1/152 |
| | Forging..... | M, I, E.C. | 1 | 1/152 |
| | Mach. Tool Work..... | M, I, E | 2 and 3 | 1/152 |
| | Mach. Construction..... | I | 3 | 1/152 |

M = Mechanical Engineering
E = Electrical Engineering
I = Industrial Engineering
C = Civil Engineering
A.E. = Aeronautical Engineering
Ch. = Chemical Engineering
E.C. = Electro-Chem. Engineering
P.D. = Pre-Dental

auxiliary equipment, the care of equipment, power transmission, millwrighting, problems of management, and factors of cost. Further, it seems desirable to make provisions to permit those students who qualify to conduct investigations by themselves, or to work on projects of a research nature already under way, so as to become acquainted with methods employed to determine new knowledge and to develop them as possible research types.

The replies to the question "What required shop courses should be offered" are shown in Table 2. Under each school the name of the course is given; the students required to take that course, whether mechanical, electrical, etc.; the year the

course is offered; and the hours of the course expressed as a function of the total hours or units required for graduation.

It is seen that in most schools several courses in shop practice are given; some of these are continuations of others, but most are for comparatively few hours. Most of the courses are for two hours credit, many are for three hours credit, and only in two instances, foundry practice at Missouri and foundry and machine shop at Michigan, are there four-hour courses. Usually a course of few credit-hours means that the class meets but once or twice a week, so that the continuity of the work is broken. It seems desirable for this reason that the course be at least of three hours credit. The two-hour or four-hour course as given at the University of Michigan has proved to be very satisfactory in that it is scheduled for a four-hour period, either from 8 to 12 A.M. or 1 to 5 P.M. The first hour is spent in the classroom and the following three hours are spent in the laboratory. A two-hour course calls for one such meeting and a four-hour course for two meetings a week. With a three-hour course, the balance between the laboratory and classroom work would be broken, so that more time would either have to be devoted to the classroom work or the laboratory work.

Table 3 summarizes the required shop work in the different curricula. For instance, at Michigan ten hours of credit in shop work are required of mechanical engineering students. This is equivalent to 7.15 per cent. of the total of 140 credit hours required for graduation. Table 3 shows that the required shop practice work for mechanical engineers ranges from 3.29 to 8.45 per cent. (Stanford excepted); for electrical engineers, from 1.43 to 5.7 per cent.; for civil engineers, from 1.43 to 3.9 per cent.; for chemical engineers, from 1.43 to 2.94; and for industrial engineering students, from 3.95 to 10 per cent. Professor Arthur B. Domonoske of Stanford University[1] points out that all engineering students at Stanford University are required to take shop practice amounting

[1] "The Importance of Shops in University Training," paper delivered at the Western Metal Congress and Exposition, under auspices of A. S. S. T., in Los Angeles, January 14 to 18, 1929.

to about two per cent. of the curriculum, but mechanical engineering students are advised to elect at least one per cent. more. The mechanical and electrical engineering students at the University of California take required shop work amounting to above five per cent. of the curriculum.

The total time to be devoted to required shop courses for each curriculum must, of course, be decided upon by the authorities of each school. Certainly no more time than is absolutely necessary should be devoted to laboratory work as such.

TABLE 3

REQUIRED SHOP WORK IN THE DIFFERENT CURRICULA

| College | Curricula | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mech. Eng. | | Elect. Eng. | | Civil Eng. | | Chem. Eng. | | Indus. Eng. | | Aero. Eng. | |
| | Hrs. | % | Hrs. | % | Hrs. | % | Hrs. | % | Hrs. | % | Hrs. | % |
| Cornell.... | 9 | 6.42 | 8 | 5.72 | 4 | 2.86 | | | | | | |
| Illinois.... | 12 | 8.45 | 6 | 4.22 | | | | | | | | |
| Iowa Univ. | 7 | 5.07 | 3 | 2.18 | | | 3 | 2.18 | | | | |
| Michigan.. | 10 | 7.15 | 2 | 1.43 | 2 | 1.43 | 2 | 1.43 | 10 | 7.15 | 6 | 4.28 |
| Minnesota | 12 | 5.9 | 8 | 3.92 | 8 | 3.92 | 6 | 2.94 | | | | |
| Missouri.. | 8 | 6.67 | 4 | 3.33 | 4 | 3.33 | 2 | 1.67 | | | | |
| Ohio State | 19 | 8.08 | 12 | 5.10 | | | 6 | 2.50 | 24 | 10.2 | | |
| Penn State | 5 | 3.29 | 4 | 2.63 | | | | | 6 | 3.95 | | |
| Wisconsin | 10 | 7.15 | 4 | 2.86 | | | 4 | 2.86 | | | | |
| California. | | 5 | | 5 | | | | | | | | |
| Stanford.. | | 2 | | 2 | | 2 | | | | | | |

Undoubtedly the laboratory part of shop practice is only a minor part of the subject. Much time can be saved and a great deal more subject matter covered with well planned and carefully administered classroom work. This also gives the student a chance to become acquainted with a very large field otherwise impossible to cover.

Table 2 shows that most shop courses are given during the first, second, or third years. The courses given in the first year are likely to serve for orientation purposes and emphasize manual training. While this work may bring the student in contact with machinery for the first time and teach

him how parts are constructed, it must be so limited that its value is questionable. Shop courses should be given as an integral part of the curriculum and tied up in as many ways as possible with the other courses. The first course in shop practice at the University of Michigan is for two hours credit only—all that are available under the present crowded condition of the curriculum. Because of this limited time, the course is confined to the working and treating of wrought iron and steel. This course is a pre-requisite to the sophomore course Chemical Engineering 1, which treats of building materials in general and is required of all engineering students.

Foundry and machine shop are obviously subjects including a large field, and to cover, even briefly, the many phases of each subject more than a two-hour course is necessary. Table 2 shows that these subjects are covered by at least two courses in a number of schools. Often, the first course covers an introduction to the subject with elementary work in the laboratory dealing with simple practice; the second class may continue this or take up problems incident to mass production. At Michigan, the course in metal working and treating is a pre-requisite to the only required course in foundry and machine shop practice, in which the whole field of each subject is covered as a unit. Advanced work of an elective nature is offered to those interested. Foundry and machine shop courses are offered during the third year, so as to be correlated better with other courses, such as design, accounting, metallurgy, etc. In answer to the question addressed to several of the midwestern universities as to the purpose of each specific course, the majority of reports obtained applied to each specific course in agreement with the reports listed in Table 1, which gives the general purpose of shop courses.

The contents of each course, and the relation of the various subjects covered, to other courses, such as drawing, design, metallurgy, metallography, engineering mechanics, are varied with the different schools because of the types of organizations. In some instances, the subjects referred to have been developed in isolated units of the college over a long period of years. In other instances, one subject has been an outgrowth of a de-

partment originally planned for another subject. These factors vary with the personnel in charge of the various phases of work, as well as with the school policies. Without a doubt, shop work covers many or all of these other subjects and should be taught in such a way that there is complete correlation with the work covered in the other departments. Drawing and design, for instance, should be taught in such a way that the student may use them as a tool, when taking shop courses. In shop practice, considerable time is devoted to the subject of nomenclature, standards, allowances, tolerances, and standard sizes of materials, tools, threads, gears, etc. This might well be prepared for in the preliminary drawing or design work. Again, shop work is a correlating unit between the subjects of metallurgy, metallography, engineering mechanics, machine design, and management. In the practical mechanics of metals, the metallurgy of the specimen must be considered. Special courses in these various subjects should go much more into theoretical detail.

Table 4 lists a number of opinions as to whether shop courses should be given during the first, second, third, or fourth year, together with the reason. It is to be noted that there is considerable difference of opinion, some indicating that it is desirable to provide these courses as early as possible; others that the first and second years are preferable; and still others that courses should never be given the first year. A composite of these answers would indicate the desirability of presenting shop courses during the first three years or all four years of the curriculum.

It is felt that the method of conducting a course in shop practice has much to do with its success. With little classroom work, the student is left to learn what he can from shop demonstrations or even short talks in the laboratory. Because of noises or other distractions, the average student loses a large part of the information given. A shop practice course does not necessarily mean working in the laboratory. Much is to be learned of the principles, materials, equipment, and practice, and even the operation of the equipment in the classroom. It seems desirable that the classroom work con-

TABLE 4

REPLIES TO THE QUESTION, "SHOULD SHOP COURSES BE GIVEN DURING THE FIRST, SECOND, THIRD, OR FOURTH YEAR, AND WHY?"

| College | Replies |
|---|---|
| Cornell..... | During the first three or all four years. Better curriculum arrangement; more satisfactory results; and better for the student. |
| Iowa Univ..... | Never the first year because greater investment in equipment is necessary for a larger number of students. Prefer second year because of better relation with drawing and design work. Fourth year preferred for production because students are accustomed to make accurate reports and generally are more interested. |
| Michigan..... | Some work should be given early to acquaint the students with materials. Work in the latter part of the curriculum is desirable that technique of operations and methods of manufacture may be studied, and that better correlation may be obtained between courses, such as design, economics, metallurgy, etc. |
| Minnesota..... | First and second preferable. It leaves more time for advanced technical work. |
| Missouri..... | Courses given in the first year are largely due to established curriculum and program. Courses are given in the fourth year to mature students, introductory to their early entrance in the field of production. |
| Ohio State..... | Shop work should be given during the second and third years. Freshmen are too young and seniors are too ripe for best results. |
| Penn. State..... | Desirable to get in courses as early as possible. Present place is determined entirely by ease of scheduling and teaching load. |
| Wisconsin..... | Should be given all four years in mechanical engineering and at least two years for chemical, electrical, and mining engineers. Keeps students in active touch with industrial problems. |

sist of assignments from a textbook, oral and written quizzes and discussions, and the working of problems. At Michigan, one hour in the classroom per week with its assignments is equivalent to three hours in the laboratory, as far as credit hours are concerned. The method of determining the final grade of the student, however, is as follows:

| | |
|---|---|
| Oral quizzes and fifteen-minute writtens | 12½ per cent |
| Problems | 12½ per cent |
| Bluebooks | 12½ per cent |
| Laboratory Work | 37½ per cent |
| Final Examination | 25 per cent |

In other words, the laboratory work is given simply to demonstrate and to permit first-hand contact with the subjects covered in the classroom.

The ratio of the hours spent in the classroom to those in the laboratory per week in a number of the universities is shown in Table 5. It is seen that the ratio between class work and laboratory work averages about 1 to 3. The range, however, is from 1 to 1 for the introductory course at Cornell to 1 to 7 for the machine shop course at Minnesota. The greater this ratio, the less the time that can be spent for outside reading, the working of illustrative problems, and general assignments.

TABLE 5

RATIO OF HOURS SPENT IN THE CLASSROOM TO THOSE SPENT IN THE LABORATORY, PER WEEK

| College | Course | | | | | |
|---|---|---|---|---|---|---|
| | General | Woodworking | Forge | Foundry | Machine | Average |
| Cornell | Introductory Laboratory 1–1 | 1–3 | | 1–1 | 1–3 | |
| Illinois | | 1–3 | | 1–3 | 1–3 | |
| Iowa Univ. | | | 1–2 | | | 1–4 |
| Michigan | | 1–3 | 1–3 | 1–3 | 1–3 | 1–3 |
| Minnesota | | 1–5 | 1–5 | 1–5 | 1–7 | |
| Missouri | Factory Production 1–3 | 1–3 | 1–4 | | 1–4 | |
| Ohio State | 3-hr. courses | | | | | 1–6 |
| | 2-hr. courses | | | | | 1–4 |
| Penn State | Production Methods 1–2 | None | None | None | None | |
| Wisconsin | Advanced Courses 1–3 | 1–5 | 1–5 | 1–3 | 1–4 | |

TABLE 6

THE NATURE OF THE CLASSROOM WORK IN SHOP PRACTICE

| College | Purpose | Blue-books | Prob-lems- |
|---|---|---|---|
| Cornell..... | Principles, tools, and methods are studied. In senior year, students are assigned problems involving many shop features, such as layout, labor, cost, etc., which involves no machine work. | | |
| Illinois..... | Class work consists of instruction in principles, tools, and methods. | | Yes |
| Iowa Univ..... | Construction operation and possibility of machine tools and measuring equipment are studied. As little similar exercise work as possible. Use drawings, but no problems. Lectures and demonstrations. | | None |
| Michigan..... | Principles, tools, equipment, and methods are studied. | Yes | Yes |
| Minnesota..... | Principles, problems, equipment, and methods are studied. Quizzes and reports required. Demonstrations in the shop are in addition to a separate period for recitations. | | Yes |
| Missouri..... | In all shop courses the jobs are presented as problems. Instruction manuals are provided for each student in which operation (how to do) sheets and information sheets are treated separately. | | |
| Ohio State..... | "We take up the general principles underlying the work, the tools, methods, machines, etc. In general, this work follows the work in the shop. Demonstrations may also be held in the classroom in addition to the above." | | Occa-sionally |
| Penn State..... | Production principles of the particular jobs are explained. Use of tools, methods, and machines of that job are studied. | None | None |
| Wisconsin..... | "For new and possible applications, as well as the study of principles, tools, equipment, methods, etc." | | |

Table 6 shows a summary of the nature of the class work at the different schools. The question asked was "is the class work to explain the shop work, or are principles, tools, equipment, methods, etc., in general studied? Are bluebooks and problems a part of the classroom work?" In most cases the object is to teach principles and technique, rather than manual training. Blue books and written quizzes do not seem to be a general requirement, and problems are required in the minority of courses.

The buildings and equipment available undoubtedly have an influence on the instruction in shop practice. The annual appropriation for new equipment, tools, experimental apparatus, and material to be used also indicates in a way the progressiveness of this type of work. To be sure, no school can expect to have the most modern types of equipment; neither can they afford to have a very great variety. A happy medium, however, might reasonably be expected so that the student will not be given misinformation. It is not reasonable to expect that during every laboratory period every piece of apparatus will be used. It is quite impossible to start a new class in the laboratory without giving them all work which is elementary and similar in character. As the classroom work advances, covering additional phases of the course, and the students become a little more acquainted with the equipment, they can be divided into small groups and assigned to more individual or advanced work.

Table 7 shows the floor space per student in shop work in some midwestern universities as compiled by Professor S. C. Shipley of the University of Minnesota in January, 1928. This shows the floor space occupied by each laboratory, the maximum number of students per section, and the average square feet of floor space per student for the pattern, foundry, forging, and machine tool laboratories. The floor space per student in woodworking or pattern-making ranges from 86 to 231 square feet; the floor space per student in the foundry laboratory ranges from 87 to 240 square feet; the floor space per student in the forge or metal working laboratory ranges from 66 to 270 square feet; and the floor space per student in

TABLE 7

FLOOR SPACE PER STUDENT IN SHOP WORK IN MID-WESTERN UNIVERSITIES, JANUARY, 1928.

| College | Pattern | | | Foundry | | | Forge | | | Machine | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Floor Space | No. of Students | Space per Student | Floor Space | No. of Students | Space per Student | Floor Space | No. of Students | Space per Student | Floor Space | No. of Students | Space per Student |
| Iowa State | 4,560 | 30 | 152 | 2,700 | 30<br>20 | 90<br>135 | 2,625 | 23 | 114 | 5,040 | 20<br>50 | 252<br>100 |
| Iowa Univ. | 2,590 | 12<br>15 | 173 | 2,200 | 12<br>15 | 147 | 2,590 | 12<br>15 | 173 | 2,590 | 12<br>15 | 173 |
| Illinois | 5,666 | 40 | 140 | 7,140 | 40 | 178 | 3,776 | 14 | 270 | 7,968 | 41 | 193 |
| Kansas | 2,000 | 20 | 100 | 4,000 | 20 | 200 | 2,000 | 10 | 200 | 4,500 | 20 | 225 |
| Michigan | 2,700 | 12 (Elective) | 225 | 7,200 | 30 | 240 | 6,000 | 40 | 150 | 7,800 | 20 | 390 |
| Minnesota | 4,630 | 40 | 116 | 3,780 | 40 | 94 | 2,640 | 40 | 66 | 4,550 | 40 | 114 |
| Missouri | 2,550 | 24 | 106 | — | — | 0 | 2,550 | 24 | 106 | 3,400 | 34 | 100 |
| Nebraska | 4,620 | 20 | 231 | 4,100 | 20 | 205 | — | — | — | 4,566 | 20 | 228 |
| Ohio | 3,150 | 24 | 128 | 4,500 | 20 | 225 | 4,000 | 24 | 163 | 8,304 | 45 | 185 |
| Purdue | 8,640 | 75<br>100 | 115<br>86 | 5,250 | 40<br>60 | 131<br>87 | 5,250 | 30<br>50 | 175<br>105 | 8,640 | 40<br>60 | 216<br>144 |
| Wisconsin | 4,200 | 20 | 210 | 2,565 | 12 | 214 | 2,460 | 20 | 123 | 6,214 | 39 | 159 |

the machine tool laboratory ranges from 100 to 390 square feet. It is safe to say that the above table does not necessarily mean that each student actually occupies this space as a working space, but that some space is idle during part of the course as the students are shifted from one phase of the work to another. The maximum number of students per section may also account for the variation in floor space per student, as the low limit may be due to insufficient instructors. Certainly the space and cost of instruction is going to increase as the instruction becomes more individual and varied.

Table 8 shows the answers to a question addressed to a number of the midwestern schools as to the cost of instruction. This information is in response to the following questions:

(*a*) Total salaries plus wages of Department of Shop Practice, including director, superintendent, instructors, and clerks.

(*b*) Total student credit hours per twelve months, July 1, 1927 to June 30, 1928.

(*c*) The cost per student credit hour.

The results show a rather wide variation in cost per student credit hour at the different schools from $5.33 per student credit hour to $18.49 per student credit hour. This is undoubtedly due to the method of handling the work and the nature of the course.

TABLE 8

COSTS OF INSTRUCTION BASED ON STUDENT CREDIT HOURS

| College | Total Salaries and Wages over Total Student Credit Hours | | |
|---|---|---|---|
| | Salaries and Wages | Student Credit Hours | Cost Per Student Credit Hour |
| Cornell | $22,150 | 1.895 | $11.68 |
| Iowa Univ. | 9,350 | 574 | 16.30 |
| Michigan | 28,100 | 1,536 | 18.29 |
| Minnesota | 21,100 | 2,851 | 7.40 |
| Missouri | 7,400 | 1,388 | 5.33 |
| Ohio State | | | 6.93 |
| Penn State | 22,320.57 | 1,207 | 18.49 |

**Advance Credit.** Because of the wide variation in purpose, scope, content, and time devoted to shop courses among the different colleges, it is difficult to adjust credit when a student transfers from one to another. The practice at Michigan in adjusting advance credit for the first course, which is given during the freshman year, is to require the student transferring to Michigan to take a two-hour written examination which covers the subject in a general way. It is realized that the students may have had this course several years previous to the transfer and that many of the details have been forgotten. It is also realized that the nature of the courses may vary over a wide range. A large number of students entering the University Engineering College come at the end of their first or second year from a city college or junior college. Some come even from high schools where they may have had work supposed to cover the content of the university course. As a general rule, these high school students are given only entrance credit in their shop work because of its close proximity to manual training and due to their lack of knowledge of principles. Those students obtaining 50 per cent. or more on this examination are given advanced credit; those obtaining between 20 and 49 per cent. are excused from the requirement; and those below 20 per cent. have to take our course. To the writer this seems entirely fair, particularly to those students who must take our course as a requirement for graduation. There is, however, some opposition even among our own faculty to this practice, as it is felt that students with better grades should be admitted without an examination, or those students coming from the schools with which we are better acquainted may have had a course quite similar to our own. The results of these examinations, however, indicate that often the student with good grades fails to pass the examination and that a large majority of the students coming from the better schools or junior colleges where a similar course is taught fail to pass.

It seems, however, that there is little opposition to the giving of such examinations in other courses, such as languages, chemistry, physics, etc., for advanced credit, so that some of

the objections to examinations in shop practice are, undoubtedly, the result of a prejudiced mind. If shop practice is to be put on an academic plane comparable with other college and university subjects, certain standards or measuring instruments must be adopted whereby the students' ability can be determined.

Examinations for advanced credit in foundry practice and machine shop practice have been abandoned, first because of the objection by certain members of the faculty, and second because of the inability of the student to pass what might be termed an "easy examination" in the subject matter covered. The present practice in these courses is to give advanced credit for work of an equivalent number of hours in a reputable school. One difficulty, however, is that these courses at Michigan are both four credit hour courses, whereas the majority are only two or three. In such cases, the student may be given credit for the hours he has covered and be excused from the remainder of our course; or he may be required to take part of our course, being excused from any work he has already had. Many students come to us having had practical experience in industry. In all of the cases in which these students have been excused from the laboratory work and required to take the classroom work with examinations, problems, writtens, bluebooks, and the final examination, they have, with only one exception, been at the bottom of the class scholastically in the final grade. This, of course, may indicate that the student has lost interest in the classroom work and, therefore, does not study; or it may reflect the importance of the laboratory work in illustrating the work covered in the classroom.

## Conclusions

In summarizing this discussion, the following conclusions representing the opinion of the author are given:

1. That the purpose of shop courses should be such that the object of the curriculum of which they are a part may be realized. This means that the shop course in the usual engineering school should give the student an opportunity of be-

coming acquainted first-hand with materials, their working and treating, the economic phases of various methods of production, the technique of methods of production and fabrication, and the relation of these processes and materials to the subjects of design, metallurgy, and problems of management.

2. The development of manual skill in machine operation should not be of prime importance, although the student incidentally may become quite proficient in carrying out a piece of work. It is more important that he understand the various steps necessary in executing a piece of work, the piece of equipment or machine needed for each step, the proper sequence of performing these steps, and the technique and principles underlying each operation.

3. Required shop courses should come under four main headings, as follows:

(*a*) Woodworking and Pattern Making, including metal patterns;
(*b*) Working and Treating of Wrought Iron and Steel;
(*c*) Cast Metals;
(*d*) Machining of Metals.

There are many courses which may be offered as electives dealing with various phases of these main divisions, such as power transmission, millwrighting, jig and fixture design, machine tool design, or advanced work in the study of processes, technique, labor standardization, safety, elements of management, etc.

4. Because of the lack of scientific information underlying many of the processes or operations involved in shop practice, provisions should be made to permit advanced students to carry out individual investigations.

5. Shop courses should be closely coordinated with the other courses of the curriculum.

6. Sufficient time should be allotted to each phase or course in shop practice that the principles may be studied along with the actual demonstrations. Each course should be of at least two credit hours, with three or four credit hours recommended.

7. Shop courses should be given throughout the college course. One general course dealing with materials should be given early in the curriculum, say the first year, so as to give the student definite information as to the materials with which he, as an engineer, has to work. This information will serve as a foundation for various theoretical courses dealing with materials. Further courses involving design, problems of management, etc., should be given during the latter part of the curriculum, so that they may be coordinated with other courses of study.

8. The courses should be conducted on a basis of part class work and part laboratory work. The classroom work should be such that the student is given assignments to study various subjects to learn something of the literature on the subject, the history, development, and present practice and art, and to learn that the actual processes in the shop are only a means to an end. The application of scientific information, as well as problems of management, should first be studied and then illustrated.

9. Courses in shop practice should be taught by teachers thoroughly acquainted with their subject. In order that courses may be changed continually to keep abreast of developments, the teachers desired merely for their skill are no longer adequate. They must be supplemented by scholars who are capable of recognizing desirable changes, so that scientific developments and the best practice may be brought to the student.

10. While the proper type of building to house shop laboratories may not always be available, every care should be taken that it be kept in repair and clean. The lack of sanitation is, undoubtedly, a factor influencing the student to dislike the laboratory, particularly the shop laboratory.

11. Equipment is important if laboratory work is to be conducted and, while most shop equipment is expensive, with care of selection and proper maintenance, sufficient types and varieties may be had for a comparatively small investment.

# SIDE LIGHTS ON THE LIFE OF THE AVERAGE ENGINEERING STUDENT

By L. A. DOGGETT

Professor of Electrical Engineering, Pennsylvania State College

Studies have already been made of our engineering curricula, of the professional status of our graduates, and of various other matters vital to engineering education.

In connection with curriculum studies, interest has centered around the distribution of subjects in the curriculum. Little attention has been given as yet to determining whether the curriculum as a whole is consistent with a reasonable and wholesome life for the student. Are we working the engineering student too hard? Are we monopolizing his time and so becoming responsible for the alleged narrowness of our engineering graduates? Have we loaded up our engineer to the point where his health is jeopardized? All these implied criticisms have been suggested in the last few years.

What follows comprises some evidence relevant to these questions, followed by some tentative conclusions.

In one week there are just 168 hours. The diagrams of Fig. 1 suggest in a crude sort of way a reasonable budgeting of these 168 hours by the college student. Two diagrams are submitted, one for the typical engineering school student and one for the typical liberal arts student.

A study of these diagrams shows that if the engineering student very carefully husbands his time that he will have some leisure available, available for broadening his outlook by reading or engaging in some extra curricular activity.

That there might be some connection between the engineers' scarcity of leisure, the liberal arts students' wealth of leisure, and their comparative participation in activities seemed very likely. Consequently the data shown in Fig. 2 were assembled. This information is based on data taken from one of the recent

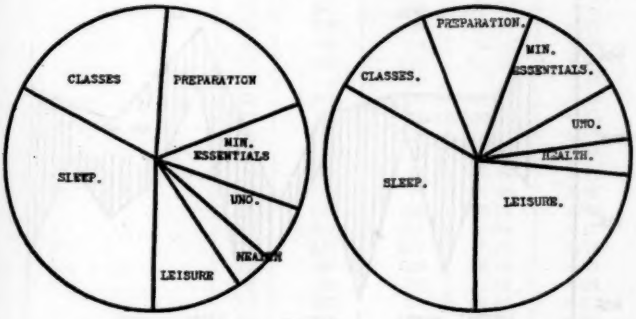


FIG. 1.

| *Engineering Student* | *Liberal Arts Student* |
|---|---|
| Sleep 56 hours, Classes 30 hours. | Sleep 56 hours, Classes 15 to 20 hours. |
| Preparation 30 hours, Minimum Essentials (meals, dressing, to and from classes) 19 hours. | Preparation 20 hours, Minimum Essentials 19 hours, Uno 10 hours, Health 7 hours, Leisure 38 hours. |
| Uno (one movie, one athletic event, one dance, one church) 10 hours. | Total 168 hours. |
| Health (one hour per day of open air exercise) 7 hours. | |
| Leisure 16 hours. | |
| Total 168. | |

student annuals. Although our engineers participated unexpectedly well in activities, we can not get away from these facts:

The engineering students, representing 32 per cent. of the college enrollment, functioned in only 23 per cent. of the ordinary activities, while the liberal arts students, representing 24 per cent. of the college enrollment, functioned in 46 per cent. of the ordinary activities.

The situation represented by Fig. 2 is a direct consequence of the leisure situation of Fig. 1.

Since the engineer did appear and under the circumstances we might say appeared so much in the various activities, it

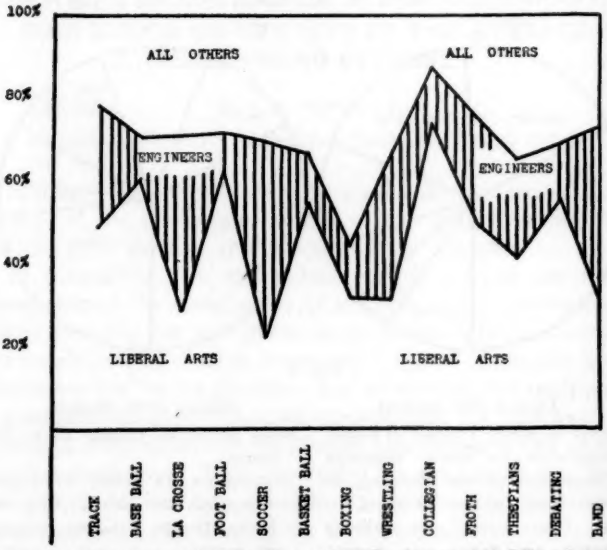


FIG. 2. Data from 1928 La Vie. 1,157 Engineers, 848 Liberal Arts Students, 1,568 all others.

might be suggested that he did it at a sacrifice to his health. Therefore a study was made of the health records for the class of 1928. The results are tabulated in Table I, which gives the number of class hours missed and the number of visits to the infirmary for various groups of students for the four year period, 1924 to 1928. The groups are arranged by curricula, by schools, and by number of credit hours. Except for the group of selected athletes, nothing resembling occupational hazard could be found. There was no correlation between number of credits and amount of sickness in the 130–150 credit range. The average engineer did not have more sick days than the average liberal arts student.

TABLE I

| Curriculum | No. Men | Hours Lost | No. of Visits to Infirmary | Hours Lost per Man | Visits per Man |
|---|---|---|---|---|---|
| Agronomy | 3 | 24 | 19 | 8.00 | 6.83 |
| Ag. B. Ch. | 12 | 241 | 100 | 20.08 | 8.33 |
| Arch. Eng. | 15 | 316 | 67 | 20.11 | 4.46 |
| Ag. Ec. | 20 | 450 | 134 | 22.50 | 6.70 |
| Ag. Ed. | 16 | 239 | 111 | 14.95 | 6.95 |
| An. Hus. | 3 | 0 | 20 | 0 | 6.67 |
| Arts—Letters | 67 | 1,013 | 541 | 15.14 | 8.09 |
| Arch. | 11 | 118 | 93 | 10.73 | 8.45 |
| Educ. | 32 | 221 | 247 | 6.91 | 7.73 |
| Ceram. | 4 | 73 | 15 | 18.25 | 3.75 |
| Chem. | 9 | 22 | 28 | 2.44 | 3.11 |
| Chem. Eng. | 13 | 187 | 76 | 14.40 | 5.85 |
| Civil Eng. | 44 | 694 | 168 | 15.75 | 3.82 |
| Com. Fin. | 109 | 1,621 | 673 | 14.86 | 6.17 |
| Dairy Hus. | 26 | 435 | 243 | 16.72 | 9.33 |
| Elec. Eng. | 79 | 967 | 519 | 12.22 | 6.58 |
| Ech. Eng. | 8 | 94 | 39 | 11.75 | 4.88 |
| For. | 12 | 197 | 79 | 16.42 | 6.42 |
| Hort. | 15 | 242 | 103 | 16.10 | 6.87 |
| Ind. Eng. | 27 | 455 | 113 | 18.84 | 4.19 |
| L. Arch. | 9 | 130 | 85 | 14.44 | 9.44 |
| Mech. Eng. | 51 | 505 | 276 | 9.90 | 5.41 |
| Met. | 12 | 188 | 70 | 15.67 | 5.83 |
| Mng. | 10 | 82 | 79 | 8.20 | 7.90 |
| Geol. | 5 | 36 | 44 | 7.20 | 8.80 |
| Poul. Hus. | 3 | 34 | 43 | 11.33 | 14.33 |
| PreLeg. | 14 | 100 | 59 | 7.15 | 4.21 |
| PreMed. | 8 | 234 | 62 | 29.35 | 7.75 |
| Phys. | 3 | 25 | 10 | 8.33 | 3.33 |
| Rail—M. E. | 2 | 18 | 1 | 9.00 | 0.50 |
| Science | 3 | 8 | 5 | 2.67 | 1.67 |
| Ind. Ed. | 3 | 12 | 12 | 4.00 | 0.67 |
| Total | 647 | 8,981 | 4,134 | 13.85 | 6.38 |
| Ag. School | 119 | 1,992 | 937 | 16.72 | 7.87 |
| Ch. & Pb. Sch. | 35 | 476 | 476 | 13.59 | 5.17 |
| L. A. School | 190 | 2,734 | 1,273 | 14.39 | 6.71 |
| Eng'g Sch. | 237 | 3,167 | 1,276 | 13.33 | 5.39 |
| Mng. School | 31 | 379 | 208 | 12.22 | 6.71 |
| Educ. Sch. | 35 | 233 | 249 | 6.66 | 7.12 |
| 130 Credits | 222 | 2,955 | 1,520 | 13.3 | 6.85 |
| 150 Credits | 425 | 6,026 | 2,604 | 14.2 | 6.13 |
| Football | 10 | 238 | 234 | 23.8 | 23.4 |
| Basket Ball | 4 | 0 | 35 | 0 | 8.75 |
| Wrestling | 5 | 33 | 58 | 6.6 | 11.6 |
| Boxing | 4 | 28 | 55 | 7.0 | 13.75 |
| Total, Athl. | 23 | 299 | 382 | 13.0 | 16.60 |

In conclusion we may picture the engineering student of today somewhat as follows: With about 30 hours per week of class hours and the necessary preparation he finds himself with little leisure, therefore with a limited opportunity to engage in extra curricular activities; compelled to husband his time, he seems to take as good care of his health as the average college student. The average college student through sickness misses about 14 hours and makes about 7 visits to the infirmary in his four years of college life.

## THE ENGLISH DEPARTMENT

# THE TEACHING OF ENGLISH IN ENGINEERING SCHOOLS

By W. A. SHOUDY

Vice Chairman Publication Committee, the American Society of Mechanical Engineers

(Discussion prepared for the symposium of graduate engineers and teachers of English, Annual Meeting, S. P. E. E., Columbus, Ohio, June 20, 1929.)

It seems hardly necessary to offer an array of evidence to justify the time taken in a discussion of this subject because the engineer is generally criticized for his inability to use effectively the English language. It is unfortunately true that, in part, this is a just criticism, but when compared with the average American business man, and in fact some other professional men, the singling out of the engineer is not altogether fair. The engineers who have risen to positions of prominence in this country do not suffer by comparison. Many papers written by such men are excellent examples of concise and lucid statements. It is true that such writings may not have any great literary merit from the standpoint of pure literature, but from the standpoint of clarity of expression there is little to be criticized. Some of these men have a natural facility for expression and others have obtained their skill by long periods of unpleasant experience, but the latter type illustrates the fact that the art of expression can be taught in the school of experience at least.

Before entering into a discussion it is always well to be sure that both sides are in agreement as to the definition of the subject. Are we primarily interested in the teaching of English? Is it not rather the art of expression with which we are concerned? Can we not clarify the discussion somewhat if we remember that what we are trying to do is to teach

the young engineer how to express himself both by the spoken and the written word. If we can once train him in the art of expression he can use the same principles in English, French or any other language.

If we can say that there is one compelling reason that directs the young man into the engineering school it is because the course will teach him to do something: to run a factory; erect a power plant; or build a bridge, and consequently he looks upon all other subjects in the course as possible tools; but generally he can see no way in which the study of English will be of any value to him.

If the subject of English were taught disguised as Effective Writing or Effective Speaking the engineering student would begin to realize that here was a useful tool and take some interest in the subject. The teaching of English in the engineering school is probably the most thankless job of the college curriculum, and this condition is probably due to the fact that the boys do not appreciate the value of the subject.

The engineering student cannot be taught the art of expression in the same way that the arts student is taught English. The arts student has already shown some interest in the art of expression and in many cases is naturally gifted in languages. He has ahead of him a literary or a business career which is dependent upon the skill in the use of language. He is interested in and appreciates beauty in language and recognizes the subject as a useful tool in later life. The engineering student, however, is usually without the gift of languages and frequently thinks of language as the art of disguising thought rather than expressing it.

It has been my privilege during the past four years to review prior to publication, a rather large number of engineering papers. These papers can generally be divided into three types:

1st—Well prepared papers, presenting valuable information, logically arranged, and in an interesting style.

2d—Poorly prepared papers, presenting valuable information, but in such a way that the meat of the article is difficult to find—and

3d—Beautifully written papers about nothing of importance.

In the teaching of English, or the art of expression, it is fully as important to eliminate the third class of writing, as it is to improve the second class. Unless the subject of English is treated from the standpoint of expression rather than rhetoric, we will continue to have frequent examples of the third class of paper, and I doubt if much improvement can be made in the second class.

It is fortunate that the engineer as a class, writes very few papers of the third type, it is usually an effort for him to write, consequently he does not attempt writing or speaking unless he has something to say. We should encourage this attitude, but we should also teach the engineer that much of the information which he thinks is unimportant, is of the greatest value to the public at large. We must therefore train him to write in such a way that the non technical public may appreciate the problems confronting the engineer, and his successes in solving these problems.

The engineer's education and life are concerned in technical details in which the public is only superficially interested. His associations in college and in later life are largely with technically trained men who are familiar with the fundamental sciences, consequently in discussing engineering problems with such associates, it is unnecessary for him to base his arguments upon first principles. He consequently gets into the habit of thinking that these fundamental principles are understood by the entire world. When he discusses an engineering problem with a non-technical world, he forgets that for a complete understanding it is necessary to discuss basic principles first. He omits this basic discussion and devotes his time to technical details and his hearer is shortly lost in a maze of misunderstanding. The engineer is consequently criticised as one who lacks the art of expression, when the truth is merely that he has talked over the head of his listener. We must teach him therefore, that before he attempts to write or speak, he must bring himself to the level of his audience and use language which they understand. This means, that in writing for engineers, he will confine

himself to important details and omit discussion of underlying principles known to all engineers, but that in writing for the layman, he must omit technicalities and discuss items which he may think unimportant, but which are of the greatest importance to the public. In the writer's opinion, a study of this method of approach is a most important division in the teaching of the art of expression; no course in rhetoric, diction or Shakespeare's tragedies will help the engineer to write effectively, unless this basic principle is first thoroughly grounded in him. When we have taught him the basic principles of expression, then we should build upon this foundation, hoping that he may develop eventually the art of fine writing.

It is not sufficient that he should be given a course in reading, in the hope that he will absorb a vocabulary. It is necessary to give him intensive drill. He should be required to write frequent themes on engineering subjects, these themes might first be addressed to an engineering audience. They should be criticised, first in regard to the arrangement of matter, whether emphasis has been placed upon important matter, and whether less important matter might not have been omitted, and finally, the statement of a logical conclusion. He should then be shown, how the choice of words will strengthen certain statements, and how repetition of words at times creates emphasis and at other times makes the writing uninteresting. These themes should later be developed into engineering reports, then engineering recommendations asking for authority to spend certain monies, letting him realize that the manner in which he presents his case determines whether or not his engineering recommendation is accepted. Later on, in the course, he should be trained in a similar manner in the writing of short articles to be read by the layman, and finally, he should receive a brief course in the better English literature, designed to create in his mind an interest in the beauty of language.

We should not overlook the fact that the engineer will be required to present his case with the spoken word. This does not mean that we should train him to be an orator, but it

does mean he should learn to speak on his feet and express his ideas effectively before a group of six or of six hundred. The training in writing should be a foundation for speaking. The drill in speaking is largely necessary to overcome nervousness in some individuals. Some types are nervous before a group of six and not before six hundred. We have made a mistake, in the past, of emphasizing training in speaking before large groups, and we have overlooked the equally important training in speaking before small groups.

Objections may be raised to these suggestions, because to carry out such a program will require more time than is generally assigned to the study of English. In the writer's opinion, this objection is not valid, because he believes that the art of expression is so important to the engineer that it is physically impossible for him to rise above the rank of the technician, unless he is able to state clearly his case and to present his facts in such a way that his superiors will accept his recommendations. We often forget that the engineer must also be a salesman. He may not be selling equipment, but he certainly must sell his ideas. It is just as important that he be trained in effective speaking, as that the salesman be so trained.

The teaching of this subject should extend throughout the entire course. Definite hours need not be assigned in the last year or two, but laboratory reports should be criticised from an English standpoint, and technical writing should be necessary even in the senior year. Possibly one of the most important items for success in this course, is the spirit of the professor in charge of the department. He must realize that his is a thankless job and yet welcome it, and have complete sympathy for the difficulties of the engineering student, but most of all, he should have complete and hearty cooperation from the other members of the engineering faculty.

# WHAT SHOULD COLLEGE COURSES IN ENGLISH CONTRIBUTE TO THE GRADUATE IN HIS FUTURE WORK?

By GEORGE A. STETSON

Associate-editor, the American Society of Mechanical Engineers

A college course in English should contribute two things to the preparation of the engineer for his future work: first, an ability to speak and write correctly, and second, an appreciation of good literature. Undoubtedly if the second of these objects is attained, the first will come more of less instinctively; but it is probably true that engineering students do not take readily to instruction either in literature or in English composition.

If I knew how to teach English to engineering students, I would be eager to see my theories put into practice. As it is, I am, perhaps, torn between admitting that we must accept a lot of drudgery in the discipline of hard work—most famous stylists have admitted that constant effort is necessary to develop and improve their art—and an attempt to make the process of education painless and delightful by some skillfully contrived scheme of motivation which sugar-coats the bitter pill and, under a guise of doing something else, teaches expression and appreciation of literature.

It is generally admitted that engineers express themselves badly. Whether they are less competent in literary expression than is any other group of non-professional writers is open to question. The fault often lies with the reader who blames the engineer for obscurity when his own ignorance stands in his way.

There are many engineers who are seriously handicapped by their inability to express themselves, either orally or in writing. Of this fact I have had abundant evidence in reviewing papers presented to the A. S. M. E. for its meetings and publications, and in listening to the discussion of these

papers in engineering meetings. To witness the halting, unimpressive, and futile transmissal of valuable and tediously soughtout truth which merits the same high skill in its presentation that it received in the shop, field, or laboratory is indeed distressing. Those to whom the subject matter is of most vital concern, and who are convinced in advance of its value, will pick from the strange assortment of statements, data, and illustrations what appears to them to be most useful, but to the rest of the world the paper might better have never been written. Here is the failure just short of success which thwarts men when they attempt to interest others in what interests them. Sometimes this means little more than failure to make the most of one's self, to market one's particular ability or accomplishments to the best advantage, or to forfeit some part of that kudos which is gratifying even to the most modest. More frequently, though, the failure entails disaster in some eagerly sought project and the disappointment which comes from having one's charished schemes cast aside or undeveloped. How many days and nights of hard work have been wasted becouse of a poorly prepared report, or a stupid speech?

There are at least three occasions when engineers are desperately in need of all of the art which professional writers and speakers have at their command: (1) when they address their fellow engineers on technical subjects, (2) when they report on engineering projects to their superiors, and (3) when they present technical subjects to a lay audience. On each of these occasions the engineer needs exactly the same technique that any other person would employ, except that perhaps there can be less appeal to emotion and less expression of personal opinion, with a greater appeal to reason and greater reliance on the potency of facts.

The principles of good writing and good speech making are the same for engineering as for other subjects. Engineers fail in their writing by disregarding these fundamental principles. Most poor papers lack a definiteness of idea which leaves the reader wondering what the author was driving at. Titles are inadequate and poorly chosen. The object of the paper is not

always stated. The author at times assumes a knowledge of the subject which the reader does not have. There is a failure to develop logically the argument with proper careful attention to the elements of unity and coherence. Details clutter the paper to the confusion of fundamental ideas—perspective is lacking. Conclusions are usually omitted, and naturally emphasis is faulty.

Most authors would profit by remembering the rule invoked by good preachers that no soul is saved after twenty minutes. Lack of skill leads to clumsy and wordy papers which in most cases can be better stated in fewer words. In preparing oral discussion of papers for printing editors seldom use more than one-third of the words of the speaker. Like sampling coal, the preparation of a good paper may be improved by a judicious quartering until a representative minimum remains.

The preparation of reports is as practical and technical a matter as an engineer could ask for, yet good reports are rare. One rule is to tell everything on the first page, on the theory that if a reader doesn't find there what he wants to know he will not take the trouble to look for it elsewhere. Reams of paper may be filled with the elaboration of various details of the subject, but a busy man who has competent advisors is not to be expected to digest all of a report let alone hunting through it for the answer to the specific question he asked. He has a right to find the answer on the first page.

Addressing the layman is a seriously difficult matter. Few engineers are competent publicists yet many such men are needed. Some engineering student may well look forward to a profitable and useful career as spokesman for his profession. Engineering projects cost money and court opposition. They usually result in radical changes in the mode of life or customs of people. Favorable action upon them must be cultivated through the press, the radio, the open forum, the town meeting. The inarticulate engineer, able to conceive and carry out these projects but unable to stir public opinion in their favor, may complain about the shortsightedness of his fellow citizens, but the burden of proof is on him and if he fails to

command respect for his schemes the fault is at least somewhat his own.

In the appreciation of literatures the engineer should be no less competent than any other educated and cultured citizen. It would not be difficult to point out conspicuous examples of engineers to whom belles lettres are as familiar as they are to members of any other profession. Without the background of a classical education, many engineers have accumulated extensive libraries and have discovered for themselves the great masterpieces of the world's literature. An appreciation of literature, a love for good reading, hours well spent among those who have preserved the life and philosophy of other times in the covers of books will do much to offset that criticism of narrowness frequently made of the engineer. While the engineer looks forward, rather than backward, and deals with new things rather than the old, his influence on civilization will be more intelligently exercised if in his background there are the experiences of former civilizations and the wisdom of other less technical and scientific minds. He is a dangerous man indeed who arms his petty egotism with the possibly disastrous power of science and technology and does not have the humility which reverences the essentially evolutionary character of the age-long process of civilization.

Here is a task for teachers of English, to awaken the realization of the necessity for literary expression, to develop what ability the engineering student may have, and to show him what a wealth of wisdom and what inspiration and intellectual satisfaction may be had from literature.

Mr. Shoudy has made some suggestions for the teaching of English to engineering students. I have commented to him that the difficulty in his program lies in finding the right teacher.

The man must possess in a marked degree the characteristics he wishes to develop in his pupils—a fundamental knowledge and appreciation of science and engineering, an ability to express himself and inspire others, and a love for literature which comes from wide reading.

## COLLEGE NOTES

**New York University.***—It is not often that a college has the rare advantage of benefitting by the long and faithful service of a founder. The ideals and aspirations which nearly always characterize the early years of an institution are all too often lost sight of and forgotten in the rapid changes in policies which accompany changes in personnel.

Dr. Charles H. Snow, more than any other individual, has title to the claim of creator of the present College of Engineering of New York University. For thirty-five years his progressive idealism has directed its destinies. Its growth and its present high rank among technical schools are testimonies to the calibre of service Dr. Snow has rendered as Dean. Working in a field which has experienced tremendously rapid strides during the last half century and occupying a post where it was vitally essential to keep abreast and even ahead of current developments, Dean Snow's activities have placed him in the front rank of America's technical school educators and research workers.

In the retirement of Dean Snow to private life, the College of Engineering and the University will suffer a definite loss. However, the firm impression which the personality of Dean Snow has had on the character of the College of Engineering cannot fail to play an important part in the future destiny of the institution.

* "Daily News."

## NECROLOGY

### J. R. BENTON

Dr. Benton was born at Concord, New Hampshire, June 6, 1876, and spent the first eight years of his life in a suburban community in Merrimack County in New Hampshire. His elementary education was received at Sewickley, Pa. He died suddenly January 8, 1930.

Dean Benton was one of the most distinguished leaders in the engineering field in the United States. He was the author of 24 books the last of which, "An Introductory Text-Book on Electrical Engineering," was published in 1928. His education was received at two institutions in this country, Trinity College and the University of Chicago, and abroad at the University of Göttingen and the University of Berlin. He received his B.S. and B.A. degrees from Trinity in 1897 and 1898 and his Ph.D. degree at the University of Göttingen in 1900.

Dr. Benton was a member of Phi Beta Kappa, Phi Kappa Phi, Sigma Xi and Theta Chi fraternities. He was a past president and immediate secretary of the Florida Engineering Society, the organization of which he took the lead in 1916.

The Benton Engineering Society, an organization of University of Florida engineering students, which bears his name, was founded by Dean Benton.

Prior to coming to the University of Florida, Dr. Benton occupied positions on the engineering faculties of Princeton and Cornell universities.

### RALPH WILLIS GODDARD

Ralph Willis Goddard was born at Waltham, Mass., April 20, 1887, and died at State College, New Mexico, December 31, 1929. Dean Goddard was making minor repairs in the power room of the radio station of the New Mexico College of A. & M. Arts—KOB—and was electrocuted.

He obtained his high school education at English High School, Worcester, Mass., graduated from Worcester Polytechnic Institute in 1911 with the degree of B.S. in E.E., and

received his professional degree from the same institution in 1929.

He was engaged in electrical contracting and building for a few years but gave up commercial work to join the engineering faculty of the University of Nebraska in 1913. In 1914 he came to New Mexico College of A. & M. A. as professor of Electrical Engineering. In 1920 he was made Dean of the School of Engineering and at the time of his death he was professor of electrical engineering, Dean of Engineering, director of the engineering experiment station and Director of KOB.

He was, at the time of his death, a member of the radio committee of the Land Grant College Association; Secretary of The Association of College and University Broadcasting Stations; and a member of the American Association of Engineers, the Institute of Radio Engineers, the American Institute of Electrical Engineers, the American Association for Advancement of Science, the National Electric Light Association, The New Mexico Utilities Association, The New Mexico Educational Association, the Society for Promotion of Engineering Education; a captain in the signal reserve corps and president of the Union High School board of Las Cruces.

Among other things, he invented the motorcycle side car. He was entirely responsible for the creation and building of radio station KOB, the most powerful educational station in the world, and one of the 13 most powerful stations in the world. KOB was one of the first two land stations licensed in the United States, Dean Goddard having secured its first license when only ship's licenses were granted or known, and practically the entire broadcasting equipment has been built to his special design in the College shops and laboratories.

## F. W. SPERR

The death on November 19 of Professor F. W. Sperr, from 1894 until 1926 head of the department of civil and mining engineering, at the Michigan College of Mining and Technology, was greeted with regret by mining men the country over. A generation of Tech alumni knew him affectionately, respected his professional knowledge and his ability as

a teacher, and appreciated highly the unselfish interest he took in his students. The faculty and administrative staff of the college knew him also as an indefatigable worker in many fields for the upbuilding of Michigan Tech. Among the scientific mining men of the country he stood out as an able scholar and authority on mining and engineering problems, and as a teacher peculiarly successful in equipping his students for responsible positions.

Professor Sperr was born in Jefferson, Ohio, in June, 1856. In 1883 he was graduated from Ohio State University with the degree of E.M. Following his graduation he was for five years a mining engineering and mine operator in Colorado, Arizona, and Mexico. From 1888 until 1894 he was assistant professor of mining engineering at Ohio State University. Professor Sperr came to the Michigan College of Mines in 1894 to take charge of the work in ore dressing and mining engineering.

Upon his retirement from academic work in 1926 he was appointed superintendent of grounds, an office which he was holding at the time of his death.

Professor Sperr's relation to the mining industry was by no means confined to his academic work. For many years he was secretary of the Lake Superior Mining Institute. He did much to advance the mining industry of Upper Michigan through his advocacy of the adoption of safety first principles in the Lake Superior District and through his share in prevailing upon the United States Bureau of Mines to send its mine rescue car to the district periodically for the giving of safety-first instruction.

## MINER HOWARD VALLAS

Miner Howard Vallas, Assistant Professor of Electrical Engineering, died on January 6, 1930, after a brief illness.

He began his career as a teacher upon his appointment as Instructor in Electrical Engineering in 1920, having been promoted in 1925 to the rank of Assistant Professor.

Mr. Vallas was an Associate Member of the A. I. E. E., and a member of the S. P. E. E.

## BOOK REVIEW

*The Balancing of Engines.* By W. E. DALBY. Fourth Edition. Longmans, Green & Co., 1929. 320 pages. Price $8.40.

Professor Dalby's brilliant treatise on Balancing of Engines is so well known and has been the standard work on the subject so many years, that a detailed discussion of the contents of this new edition seems to be unnecessary. The present edition exhibits the keen analysis, logical presentation and lucidity of expression which is characteristic of all Professor Dalby's writings. It should be a valuable acquisition to all engineering libraries.

In the earlier editions stress was laid upon the balancing problems of marine types of steam engines. The most significant change in the new edition is the increased emphasis on the application to railway problems. The chapter on Balancing of Locomotives has been re-written and considerably expanded, many examples from actual machines being solved. A very interesting and important chapter has been added on the Vibration of Railroad Bridges as affected by the unbalance of the locomotive. The effect of the various unbalanced forces and couples is considered in detail, and the theoretical conclusions are checked against tests made under the auspices of a special committee of the Department of Scientific and Industrial Research. This committee worked for several years on the problem, its report being completed in September, 1928. In view of the inherent difficulty of the problem the agreement between the tests and mathematical solutions is really amazing. This chapter furnishes an excellent illustration of the inter-relation between the different fields of engineering. Balancing of engines is regarded as a purely mechanical engineering problem, while bridge design is equally definitely in the field of the civil engineer. But here is a case where the unbalance of the locomotive has a very important bearing on the stress distribution in the bridge. Contrary to

common belief, engineering can not be divided into water-tight compartments.

The author has also added a new chapter on balancing of internal combustion engines. In comparison with the other parts of the book, this chapter seems somewhat sketchy. The principal arrangements of cranks and cylinders are adequately, if briefly discussed. The V type engine is considered only for the case where the two sets of cylinders are at right angles. The offset or "desaxee" engine is mentioned, but no solution is given for its balance. In the rotary type the author shows that the inertia forces due to acceleration parallel to the connecting rods form a practically balanced system, but neglects the forces due to other components of the acceleration. It is not difficult to show that these are also almost completely balanced. He tacitly assumes the center of mass of the piston to be at the center of the wrist pin.

For the rest, the material of the remaining chapters is almost identical with the third edition. Some minor changes may be noted. Klein's construction for piston acceleration has been replaced by Bennett's; the material in the various appendices of the third edition has been incorporated in the text of the fourth, etc.

The book is well printed and bound and contains very few typographical errors. It is highly creditable both to the author and to the publisher.

J. A. D.

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## CORRECTION

In the article, "Mississippi River Flood Control," by Arthur E. Morgan which appeared in the December issue of the JOURNAL OF ENGINEERING EDUCATION (New Series, Vol. XX, No. 4), the words "Executive Council of the United Engineering Societies," page 446, lines 33 and 34, should read "American Engineering Council."

## 1929–30 MEMBERSHIP CAMPAIGN

On September 13 the Secretary wrote to the representative of the Society in each institution in the United States and Canada asking him to send to this office the names of all members of the engineering faculty. On this list the Secretary marked off the names of those persons who were members of the Society and to the others he sent invitations for them to join the Society enclosing an application blank for that purpose. The names of the faculty members of the following institutions were received.

On January 28 when this notice was sent to the printer invitations had been sent to 1,484 persons as indicated on the table. 166 applications have been received to date.

The Secretary asks you to seek the men in your institution who are not members of the Society and to second the invitation which he has extended. If your institution is not listed here, ask your local representative for the reason. We are printing an application blank herewith for the convenience of those who may not have any available.

F. L. BISHOP,
*Secretary.*

| Institution | Application Blanks Sent | Applications Received | Members |
|---|---|---|---|
| Akron, Univ. of | 3 | 0 | 9 |
| Alabama Poly. Inst | 15 | 3 | 13 |
| Alabama, Univ. of | 13 | 0 | 1 |
| Alberta, Univ. of | 0 | 1 | 3 |
| Antioch College | 6 | 1 | 5 |
| Arizona, Univ. of | 0 | 0 | 9 |
| Arkansas, Univ. of | 7 | 0 | 7 |
| Armour Inst. Tech | 22 | 1 | 23 |
| Beirut, Univ. of (Syria) | 0 | 1 | 1 |
| Bombay C. E. College | 0 | 0 | 1 |
| Bradley Poly. Inst | 0 | 0 | 2 |
| Brazil-Poly. School of State | 0 | 1 | 1 |
| British Columbia, Univ. of | 0 | 0 | 4 |
| Brooklyn Poly. Inst | 0 | 0 | 18 |
| Brown Univ | 0 | 0 | 8 |
| Bucknell Univ | 10 | 0 | 10 |
| Buffalo, Univ. of | 0 | 0 | 1 |
| Calif. Inst. Tech | 26 | 0 | 7 |
| Calif., Univ. of | 0 | 0 | 8 |
| Calif., Univ. of So | 0 | 0 | 5 |
| Carnegie Inst. of Tech | 39 | 0 | 21 |
| Case School Applied Science | 12 | 3 | 29 |
| Catholic Univ | 0 | 0 | 1 |

| Institution | Application Blanks Sent | Applications Received | Member |
|---|---|---|---|
| Chicago, Univ. of | 0 | 0 | 1 |
| Cincinnati, Univ. of | 33 | 0 | 7 |
| Clarkson College | 0 | 0 | 5 |
| Clemson College | 0 | 3 | 8 |
| Colby College | 0 | 0 | 1 |
| Colorado Agri. College | 13 | 0 | 5 |
| Colorado School Mines | 37 | 1 | 11 |
| Columbia University | 27 | 4 | 25 |
| Colorado, Univ. of | 29 | 4 | 20 |
| Cooper Union | 0 | 1 | 13 |
| Cornell University | 71 | 4 | 27 |
| Cornell College | 0 | 0 | 1 |
| Dartmouth College | 0 | 0 | 4 |
| Dayton, Univ. of | 0 | 1 | 5 |
| Delaware, Univ. of | 0 | 0 | 8 |
| Denison Univ | 0 | 0 | 2 |
| Detroit University | 12 | 3 | 11 |
| Drexel Institute | 31 | 4 | 8 |
| Duke Univ | 0 | 0 | 9 |
| Ecole Polytechnique | 28 | 1 | 2 |
| Evansville College | 0 | 1 | 2 |
| Florida, Univ. of | 13 | 0 | 11 |
| Franklin and Marshall College | 0 | 0 | 2 |
| Franklin Union | 0 | 0 | 2 |
| General Motors Inst | 0 | 0 | 3 |
| George Washington Univ | 0 | 0 | 2 |
| Georgia Inst. of Tech | 41 | 1 | 19 |
| Gettysburg College | 0 | 0 | 2 |
| Girard College | 0 | 0 | 1 |
| Harvard University | 14 | 1 | 13 |
| Haverford College | 0 | 0 | 1 |
| Hawaii, Univ. of | 4 | 0 | 2 |
| Howard Univ | 0 | 0 | 1 |
| Idaho, Univ. of | 11 | 5 | 12 |
| Illinois, Univ. of | 32 | 4 | 53 |
| Indiana Univ | 0 | 0 | 1 |
| Iowa State College | 67 | 3 | 32 |
| Iowa State University | 5 | 2 | 23 |
| James Millikan Univ | 0 | 0 | 2 |
| Johns Hopkins Univ | 0 | 0 | 2 |
| Kansas State Agri. College | 62 | 11 | 36 |
| Kansas, Univ. of | 31 | 0 | 23 |
| Kentucky, Univ. of | 0 | 3 | 14 |
| Lafayette College | 3 | 1 | 11 |
| Lehigh Univ | 0 | 1 | 18 |
| Leningrad Poly. Inst | 0 | 0 | 1 |
| Lewis Inst | 0 | 0 | 1 |
| La. Industrial Inst | 0 | 0 | 3 |
| La. Southwestern Inst | 0 | 0 | 3 |
| La. State Univ | 0 | 0 | 2 |
| Louisville, Univ. of | 5 | 0 | 12 |
| Maine, Univ. of | 14 | 0 | 23 |
| Manhattan College | 0 | 0 | 7 |
| Marquette Univ | 0 | 0 | 5 |
| Maryland, Univ. of | 0 | 0 | 2 |

| Institution | Application Blanks Sent | Applications Received | Members |
|---|---|---|---|
| Mass. Agri. College | 0 | 0 | 1 |
| Mass. Inst. Tech. | 0 | 1 | 43 |
| McGill Univ | 0 | 1 | 9 |
| Mechanics Inst. | 0 | 0 | 2 |
| Mexico, Univ. of | 0 | 0 | 4 |
| Michigan College Mines | 16 | 0 | 6 |
| Michigan, Univ. of | 77 | 5 | 48 |
| Michigan State College | 0 | 1 | 12 |
| Minnesota, Univ. of | 39 | 3 | 75 |
| Mississippi A. & M. | 12 | 0 | 4 |
| Mississippi, Univ. of | 10 | 0 | 3 |
| Missouri School Mines | 19 | 2 | 12 |
| Missouri, Univ. of | 6 | 0 | 16 |
| Montana School of Mines | 0 | 0 | 2 |
| Montana State College | 0 | 0 | 7 |
| Mt. Allison Univ. | 0 | 0 | 2 |
| Nanking Tech. College | 0 | 0 | 1 |
| Nebraska, Univ. of | 0 | 0 | 21 |
| Nevada, Univ. of | 18 | 0 | 3 |
| Newark College of Eng. | 16 | 1 | 12 |
| New Hampshire, Univ. of | 9 | 1 | 10 |
| New Haven College | 0 | 0 | 1 |
| New Mexico A. & M. | 6 | 0 | 3 |
| New Mexico School Mines | 8 | 0 | 1 |
| New Mexico, Univ. of | 0 | 0 | 3 |
| New York, College of City | 0 | 0 | 6 |
| New York Univ. | 0 | 0 | 16 |
| North Carolina State College | 0 | 0 | 14 |
| North Carolina, Univ. of | 0 | 1 | 10 |
| North Dakota Agr. College | 13 | 0 | 4 |
| Northeastern Univ. | 0 | 1 | 30 |
| Northwestern Univ. | 0 | 0 | 6 |
| Notre Dame, Univ. of | 0 | 0 | 2 |
| Norwich Univ. | 0 | 0 | 4 |
| Nova Scotia Tech. College | 8 | 0 | 1 |
| Ohio No. Univ. | 0 | 0 | 3 |
| Ohio Mechanics Inst. | 0 | 0 | 2 |
| Ohio State University | 25 | 1 | 56 |
| Oklahoma A. & M. | 0 | 0 | 9 |
| Oklahoma, Univ. of | 23 | 0 | 7 |
| Oregon Agr. College | 23 | 4 | 16 |
| Pei Yeng Univ. | 0 | 0 | 2 |
| Penna. State College | 38 | 1 | 37 |
| Penna., Univ. of | 0 | 1 | 13 |
| Philippines, Univ. of | 0 | 0 | 1 |
| Pittsburgh, Univ. of | 11 | 2 | 26 |
| Porto Rico, Univ. of | 9 | 0 | 3 |
| Pratt Institute | 0 | 8 | 27 |
| Princeton University | 8 | 2 | 9 |
| Purdue University | 92 | 5 | 74 |
| Rensselaer Poly. Inst. | 0 | 0 | 12 |
| Rhode Island State College | 0 | 0 | 5 |
| Rice Institute | 0 | 0 | 4 |
| Rindge Tech. School | 0 | 0 | 1 |
| Robert College | 0 | 0 | 1 |

| Institution | Application Blanks Sent | Applications Received | Members |
|---|---|---|---|
| Rochester, Univ. of | 0 | 1 | 2 |
| Rose Poly. Inst. | 19 | 6 | 8 |
| Royal Military Inst. | 6 | 0 | 0 |
| Rutgers Univ. | 0 | 1 | 11 |
| Saskatchewan, Univ. of | 9 | 0 | 1 |
| South Dakota School Mines | 0 | 3 | 8 |
| South Dakota State Coll. | 6 | 0 | 2 |
| South Dakota, Univ. of | 0 | 0 | 5 |
| Stanford University | 23 | 0 | 14 |
| Stevens Inst. Tech. | 12 | 1 | 12 |
| St. John's Univ. | 0 | 0 | 1 |
| Swarthmore College | 0 | 1 | 5 |
| Syracuse Univ. | 0 | 0 | 13 |
| Tangshan Univ. | 0 | 0 | 1 |
| Tennessee, Univ. of | 0 | 0 | 2 |
| Texas Agri. College | 0 | 0 | 2 |
| Texas A. & M. | 45 | 6 | 30 |
| Texas College Mines | 0 | 0 | 1 |
| Texas Tech. College | 0 | 2 | 8 |
| Texas, Univ. of | 25 | 1 | 8 |
| Toledo, Univ. of | 0 | 0 | 3 |
| Toronto, Univ. of | 0 | 0 | 9 |
| Trinity College | 0 | 0 | 1 |
| Tufts College | 11 | 0 | 25 |
| Tulane University | 12 | 0 | 11 |
| Union College | 3 | 1 | 9 |
| U. S. Naval Academy | 0 | 2 | 8 |
| Utah Agri. College | 0 | 0 | 2 |
| Utah, Univ. of | 0 | 0 | 5 |
| Vanderbilt University | 0 | 1 | 6 |
| Vermont, Univ. of | 8 | 2 | 12 |
| Victoria Jubilee Tech. Inst. | 0 | 0 | 1 |
| Villanova College | 0 | 0 | 1 |
| Virginia Military Inst. | 0 | 0 | 11 |
| Virginia Poly. Inst. | 36 | 2 | 12 |
| Virginia, Univ. of | 0 | 0 | 14 |
| Washington State Coll. | 26 | 1 | 10 |
| Washington Univ. (St. Louis) | 0 | 0 | 9 |
| Washington, Univ. of | 0 | 2 | 14 |
| Wentworth Institute | 0 | 1 | 8 |
| West Virginia Univ. | 0 | 0 | 10 |
| Wisconsin, Univ. of | 0 | 3 | 35 |
| Worcester Poly. Inst. | 13 | 2 | 23 |
| Wyoming, Univ. of | 6 | 1 | 4 |
| Yale University | 0 | 1 | 40 |
| Industrial | 0 | 14 | |
| | 1,484 | 166 | |

Total Membership, December 3, 1929

| | |
|---|---|
| Individual Members | 2,212 |
| Institutional Members | 119 |
| | 2,331 |

*Return to the Secretary, F. L. Bishop, University of Pittsburgh, Pittsburgh, Pa.*

**Society for the Promotion of Engineering Education**

Date.....

THE UNDERSIGNED desiring to become a member of THE SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION

hereby agrees to conform to the requirements of membership, if elected, and submits the following:

STATEMENT OF QUALIFICATIONS

*Full Christian Name and Surname*.....
Print Last Name First Middle

*Mailing Address (Number and Street)*.....

*Post Office (City and State)*.....

*Full Title of Professional Position*.....
(Title) (Department)

*Full Name of Institution*.....

*(To be Signed by Two Sponsors)*

SPONSORS .....

.....

* The number of applications requested by their representative.